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Examining the Effects of Inquiry-Based Teaching Strategies on Community College Mathematics Students

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Examining the Effects of Inquiry-Based Teaching Strategies on Community College Mathematics Students

by

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Dedication

This dissertation is dedicated to my husband David, who never doubted I could finish – even when I had doubts myself.

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Examining the Effects of Inquiry-Based Teaching Strategies on Community College Mathematics Students

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It is well documented that students are struggling in developmental and introductory mathematics courses at community colleges across the nation. However, the reasons that these students struggle are not as well known. While numerous researchers have investigated the effects of inquiry-based learning on K-12 students, the research on this topic at the community college level is lacking. For my dissertation work, I have collected attitudinal surveys, observational data, and final exams from eight sections of a developmental mathematics course and nine sections of College Algebra at a large Texas community college. Approximately half of the instructors involved in the study incorporated some level of inquiry-based teaching strategies in their classrooms (referred to in this dissertation as "student-led" sections) while the remaining instructors employed a more direct strategy (referred to as "lecture" sections). Using this data, I investigated the relationships between teaching methods and attitudes, teaching methods and content knowledge, and attitudes and content knowledge. The evidence showed that IBL teaching strategies have a greater effect on students' attitudes for students enrolled in a developmental mathematics course than those enrolled in College Algebra. IBL teaching strategies had no positive effects on developmental students' performance on a skills-based

final exam, but student-led sections performed just as well as lecture sections. In College Algebra, participants in student-led sections scored significantly higher than lecture sections on two out of five objectives: *write the equation of a line in slope-intercept form* ($p<0.001$) and *use properties of logarithms to write an expression as a single logarithm* ($p<0.01$). Lecture sections scored significantly higher than student-led sections on one objective: w*rite the equation of an exponential function given two data points* ($p<0.05$). However, the wording of the problems for this objective differed between lecture and student-led sections. Finally, when comparing the eight Basic Math Skills objectives with the 17 attitudinal variables, 1.4% of pairs were significantly correlated on the pre-survey and 15.4% of pairs were significantly correlated on the post-survey. Of the five College Algebra objectives and 17 attitudinal variables, 16.5% of pairs were significantly correlated on the pre-survey and 7.1% of pairs were significantly correlated on the post-survey.

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Chapter One: Introduction

Statement of the Problem

Across the nation, over half of all undergraduate students are served by community colleges, which often function as a "gateway to postsecondary education for many minority, low income, and first-generation postsecondary education students" (American Association of Community Colleges, 2012). Unfortunately, approximately two-thirds of incoming community college students are not considered college ready in at least one of the critical areas of mathematics, English, or reading (Whissemore, 2010). In addition, 60 to 70 percent of such students who need developmental (remedial) mathematics courses either do not pass those courses or avoid them (and a degree) altogether (Stigler, Givvin, & Thompson, 2010). Therefore, rather than serving as a gateway, developmental mathematics courses have become a "primary barrier for students ever being able to complete a post-secondary degree" (Stigler et al., 2010, p. 2).

Numerous individuals and agencies have called for increased completion rates at community colleges nation-wide (American Association of Community Colleges, 2010), but the difficulty lies in achieving these higher rates. Stigler, Givvin, and Thompson (2010) argued that the patterns of misunderstanding among community college mathematics students are similar to the well-documented patterns among K-12 students in our nation, and that using the *same* unsuccessful methods of teaching (which emphasize "practicing routine procedures with virtually no emphasis on understanding of core mathematics concepts") will not help students to overcome the misconceptions they developed during their K-12 education (p. 2). It is time for a new approach.

Benefits of this Research

Inquiry-based learning (IBL) involves creating an environment that challenges students to create, discuss, and critique explanations and conjectures (National Council of Teachers of Mathematics, 2000). During a study of the effects of inquiry-based mathematics on 11th grade students, Chin, Lin, Chuang, and Tuan (2007) stated that essential traits of inquiry-based learning are "connecting former knowledge and experiences with the problems learners have, designing procedures (plans) to find an answer to the problem, investigating phenomena through conjecture, [and] constructing meaning through use of logic and evidence and reflection" (pp. 129-130). The study showed that inquiry-based learning promotes increased levels of metacognition among students, which has been linked to improvements in both content knowledge and problem-solving ability (Baird & Northfield, 1992; Schoenfeld, 1985, 1992).

Furthermore, in a recent study focusing on IBL courses at four major universities, researchers found that students in IBL courses reported higher learning gains than their peers in non-IBL courses. Additionally, academic records indicated that, in subsequent classes, students who had previously enrolled in an IBL course earned grades that were as good or better than students not previously enrolled in an IBL course (Laursen, Hassi, Kogan, Hunter, & Weston, 2011). The researchers also found more significant affective gains among women and minority groups than their white male peers. Given that the population of students attending community colleges has a higher percentage of female and minority students than the population attending four-year institutions, it is of particular importance to examine the effects of IBL-type strategies at community colleges on both student attitudes and achievement (American Association of Community Colleges, 2012). Finally, Laursen et al. (2011) observed modest correlations between self-reported learning gains and changes in students' beliefs, motivations, and strategies.

Addressing the gap in educational research at the community college level, this research will contribute to the field by incorporating certain components of the Laursen et al. study. While study replication in educational research is difficult (if not impossible), this study is comprised of three of the prior study's main components: attitudinal surveys, classroom observations, and content knowledge assessments. The attitudinal surveys and classroom observations were modified slightly for the community college population, but are very similar to the prior study. However, content knowledge assessments in the form of final exams were already in use at the community college and were very different from content knowledge assessments used by Laursen et al. During the data collection phase, participants were enrolled in courses taught by ten different instructors at a large Texas community college. The study includes seventeen different sections taught by these ten instructors. Some of the instructors used more direct teaching methods, while others incorporated varying degrees of teaching strategies similar to IBL (such as group work, class discussions, and student presentations). Sections in which instructors incorporated these particular three teaching strategies will be referred to as "student-led" sections for the purposes of this dissertation. The sections in which instructors used more direct teaching methods will be referred to as "lecture" sections. It should be noted that instructors often incorporated a mixture of both student-led activities and direct methods of instruction. Schwartz and Bransford (1998) have provided evidence that developing the prior knowledge students need to understand a lecture or text can create a more appropriate "time for telling" than lecture alone. This idea should not be overlooked, and an ideal study would investigate the effectiveness of using direct instruction in conjunction with inquiry-based learning teaching strategies. However, due to the small sample size in this study, each instructor's methods were categorized in one of only two categories.

Students were not assigned randomly to each of the two teaching strategies since they are responsible for enrolling in classes themselves. However, using data collected as part of the attitudinal survey, I compared nine background characteristics of the students and found no statistical differences between the two types of instruction method for College Algebra or Basic Math Skills. Additionally, in Basic Math Skills sections I compared the students' incoming arithmetic skills and found no differences among the groups. Specific details of these comparisons are reported in Chapter Three. The goal of the study is to investigate the relationship between teaching methods and student attitudes about mathematics as well as the relationship between teaching methods and content knowledge. Additionally, this research investigates the correlation between student attitudes about mathematics and content knowledge among the target population of community college students.

METHODS AND RESEARCH QUESTIONS

Two of the major components used to collect data in this dissertation are based on those developed by the Laursen et al. research team. In particular, modified versions of the attitudinal survey and classroom observational protocol were developed. Minor changes were made based on the difference in population and are described in the methodology section of this dissertation. Additionally, final exams were collected for each student involved in the study. Classroom and personnel constraints limited this particular study to these three main components. Thus, the research questions are:

1. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' attitudes about math?

2. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' mathematical content knowledge?
3. Are community college students' attitudes about mathematics connected to their mathematical content knowledge?

To address these questions, data was collected from eight sections of Basic Math Skills (the first course in a developmental math sequence at large a Texas community college) and nine sections of College Algebra. The three primary types of data collected were: (1) attitudinal surveys, (2) final exams, and (3) classroom observations. The instruments used to collect data are furthered described in Chapter Three and attached in Appendix A.

SUMMARY OF RESULTS

Research Question 1

Analysis of the survey data was accomplished through the creation of seventeen composite attitudinal variables based on student responses. Using *t*-tests, average changes in composite attitudinal variables were examined for four groups: Basic Math Skills – Student-led, Basic Math Skills – Lecture, College Algebra – Student-led, and College Algebra – Lecture. Individual sections were classified as "student-led" or "lecture" based on the observational data. Increases (from the beginning of the semester to the end of the semester) in three composite attitudinal variables were found to be significant among the Basic Math Skills – Student-led group, although no differences were found for the Basic Math Skills – Lecture group. Three differences were found for each of the College Algebra groups. Due to the large number of *t*-tests performed, I will discuss the possible need for

Bonferroni adjustments. Bonferroni adjustments are used to control the overall Type I error rate of a study when multiple comparisons are run.

Research Question 2

Final exams were scored according to a rubric that I developed and checked for reliability. Exam data was compared among class types. For Basic Math Skills, the rubric contained eight objectives seen throughout the exam (all exams were the same for student-led and lecture sections). There were no statistical differences between lecture and student-led sections on any of these eight objectives.

The College Algebra rubric was used to analyze five questions that were similar on the student-led and lecture final exams (these exams were not the same). Student-led classes scored significantly higher two objectives: *write the equation of a line in slope-intercept form* (p<0.001; a mean score of 0.978 vs. 0.836) and *use properties of logarithms to write an expression as a single logarithm* (p<0.01; a mean score of 0.781 vs. 0.570). However, lecture classes scored significantly higher on another objective: *write the equation of an exponential function given two data points* (p<0.05; a mean of 0.803 vs. 0.598). This last result could be due to the wording of the two problems, which was not ideal for comparison purposes and will be discussed in Chapter Five.

Research Question 3

Using the 17 composite attitudinal variables and the final exam scores, I was able to examine the correlation between student attitudes and content knowledge. For the Basic Math Skills group, the pre-survey showed significant correlations for 1.4% of the pairs, but the post-survey showed significant correlations for 15.4% of the pairs. In the College Algebra group, the results were reversed. For pre-surveys, 16.5% of the pairs were significantly correlated and 7.1% of the pairs were significantly correlated on the post-survey.

FURTHER CHAPTERS

In the following chapters of this dissertation, I will further develop the significance of this study through a literature review. Additionally, I will discuss in detail the methodology used to analyze the data and address the research questions at hand. Following this, I give the results from the individual statistical analyses that I performed using the survey and final exam data. The final chapter gives a discussion of the results and implications for future research.

Chapter Two: Literature Review

THE PROBLEM

As mentioned in Chapter One, an unfortunately high percentage of incoming community college students are in need of remediation in at least one of the critical areas of mathematics, English, or reading (Whissemore, 2010). With over 99.4% of all two-year public colleges offering remedial education, there is a large demand for such courses (National Center for Education Statistics, 2012). It has been documented that even among high school graduates, a significant portion (one-third) may need to enroll in developmental mathematics courses (Fong, 2008; Greene & Forster, 2003). Many community colleges require successful completion of three or more semesters of remedial mathematics before students can enroll in credit-bearing courses. Unfortunately, the attrition rate in these classes is substantial. In a study of 57 colleges, less than 50% of students who were referred to remedial courses actually completed the sequence (and thereby were able to enroll in a credit-bearing course) (Bailey, Jeong, & Cho, 2010). Remedial students are also much less likely to complete a degree or certificate than students who require no remediation, and the need for remediation negatively affects African American and Hispanic students more than their white peers (Bailey, Jenkins, & Leinbach, 2005). Of the students who were actually placed three levels down from a college-level mathematics course, only 10% actually went on to attain their goal of passing a college-level mathematics course (Bailey et al., 2010). Other researchers have noted that there is little evidence to suggest that remedial education actually improves student outcomes, despite national annual costs that exceed $1 billion (Calcagno & Long, 2008; Martorell & McFarlin Jr, 2011).

Furthermore, the problem of remedial education is not a new issue, nor is it one specific to mathematics. In a study of transcripts from 1981 – 1993, Adelman (1999) found that 22.5% of all grades in developmental mathematics classes were reported as either a no credit repeat, a withdrawal, or an incomplete - with an additional 8.6% of grades reported as failing (or another form of penalty grade). Thus, in total, 31.1% of grades recorded for developmental math classes indicated that the student did not successfully complete the course. The corresponding rate for remedial English/writing courses was 22% (Adelman, 1999). It was later reported that between 61 and 63 percent of students graduating in 1982 or 1992 who enrolled at a community college needed at least one remedial course (Adelman, 2004).

Data collected by Bahr (2008), in a study which followed over 85,000 community college freshmen for eight years, gives us insight into the difficulties faced by students who need mathematics credits to complete their program. Participants in the study were selected from 107 different community colleges. Of the students in the study, 81.3% initially enrolled in a remedial math course. Of these, less than 25% went on to successfully complete a college-level mathematics course. The remaining 18.7% of students initially enrolled in a college-level course, and 83.4% of these completed the course successfully (Bahr, 2008). This can also be compared to Adelman's (1999) transcript analysis, which revealed that 23.5% of student grades for College Algebra indicated unsuccessful attempts at the course.

Clearly, courses that are classified as "remedial" are not the only problem. Attrition rates in College Algebra (which is a credit bearing course at most two-year colleges) are concerning, as are the implications that these statistics have on overall student success rates. Being successful in a college-level math course within the first two years of initial enrollment is connected to the successful completion of 30 or more college credits within seven years – specifically, 83% of students obtaining this math credit (within two years) reach this milestone versus 33% of their peers who did not obtain the math credit (Moore, Shulock, & Offenstein, 2009).

Hern (2010) argued that much of the attrition noted in mathematics courses is due to the "multiplication principle" (a phrase coined by Myra Snell), which refers to the compounding attrition rates resulting from the length of most developmental sequences. Hern's example is instructive: Imagine 100 students enrolled in the first course of a three-semester developmental sequence. Assuming a completion rate of 75% in each class, 75 students would be eligible to enroll in the second course. Of course, data on these students tells us that not all of these 75 will enroll. Hern notes that if only 75% of these eligible students enroll, the original pool of 100 students has already been reduced to 56 before the second course even begins. Continuing to assume success and persistence rates of 75%, by the beginning of the third course in the developmental sequence the pool has been reduced to 32 students; by the beginning of the college-level course the pool has been reduced to 18 students; finally, approximately 13 of the original 100 students would pass the college-level course. Although Hern described a hypothetical situation, data collected by Bailey et al. (2010) told a similar story: while 29% of all students referred to developmental mathematics exited the sequence after failing or withdrawing, an additional 11% exited without ever failing a course – they simply did not enroll in the next course. These figures suggest that the hypothetical situation proposed by Hern is not unreasonable, and that the length of developmental sequences could play a large role in student success (or rather, failure). Others have also noted the need for accelerating remedial mathematics education sequences, and cite flexibility within such sequences as an important factor to achieving this goal (Biswas, 2007; Jenkins & Cho, 2012).

Additional research suggests that remedial mathematics courses are becoming more of a *barrier* for students than a path to degree completion. For example, in study of nearly 100,000 Florida college students, Calcagno & Long (2008) found that while students who were assigned to remedial courses were initially more likely to enroll in a second year, they were not as likely to eventually complete a degree. Attaining college-level mathematics credit is not only a common necessity for completing a degree – it can also be a requirement for students to even enter a program of study. Given that students who do not enter a program of study during their first year are far less likely to complete a program than those that do, this is a noteworthy problem that is again complicated by the length of most remedial mathematics sequences (Jenkins & Cho, 2012). Others have recently noted that remedial math is not actually remediating students, but continues to be a road block to obtaining a degree – one that must be addressed in order to improve completion rates (American Association of Community Colleges, 2010; Bryk & Treisman, 2010; Stigler et al., 2010).

Stigler, Givvin, and Thompson (2010) pointed out the glaring fact that for many American students, K-12 mathematics education has not only failed to be deep and meaningful, but has also left them without basic arithmetic, pre-algebra, and algebra skills. The authors believe this effect is at least partially due to K-12 teaching methods that present mathematics as a list of procedures to memorize and practice, "with virtually no emphasis on understanding core mathematics concepts that might help students forge connections among the numerous mathematical procedures that make up the mathematics curriculum in the U.S." (Stigler et al., 2010, p. 2). It has also been suggested that the college-level courses students are taking, one of which is College Algebra, are not serving the same purpose they were thirty years ago. That is, the majority of College Algebra students are not intending to take calculus or calculus-based physics, two traditional goals on which the content of College Algebra is typically based (Gordon, 2008).

Thus, not only is it possible that some mathematics courses have outdated objectives, but the little research that exists regarding community college classrooms suggests that the same unsuccessful, traditional teaching methods are being used over and over again – with the same results (Curtis, 2006; N. W. Grubb & Associates, 1999). In a literature review which examined challenges in community college education, Goldrick-Rab (2007) stated that the “notorious ‘drill-and-skill’ approach is still thought to dominate most instruction though it may not be an effective teaching style for students who are likely to already have had bad experiences with it in high school” (pp. 19-20). Moreover, most of the reforms across the nation aimed at improving developmental education success rates rarely focus on the actual teaching methods employed in such courses (Derby & Smith, 2004; Levin & Calcagno, 2007). As an example, LaManque (2009) reported on a two-year pilot program which included providing in-class counseling services to students for non-academic issues. While the study did show small improvements in student success rates for some groups of students, LaManque noted that it is difficult to determine if the effects seen were actually related to the interventions, and not due to instructor self-selection bias. Zachry (2008) has researched the effect of a few pilot programs designed to address what actually happens in the classroom, but indicated that such programs are rare.

In fact, Speer, Smith, and Horvath (2010) noted that research on collegiate-level teaching practices is virtually non-existent. Grubb and Cox (2005) reiterated that while there is significant data about community college instructors and the community colleges themselves, very little is known about student *attitudes*: "... our knowledge of students and their attitudes toward learning is sorely lacking, partly because empirical analyses of teaching usually focus on instructors rather than on students" (p. 95). Curtis (2006) also emphasized the importance of examining how standards-based teaching approaches can impact student attitudes toward mathematics at community colleges, “where students are taught in traditional formats and rarely challenged to make connections between mathematics and their personal experiences” (p. 11).

To conclude, it is clear that more research is needed on both community college classrooms and students. Different teaching methods should be examined, along with their effects on student success. In addition, community college students' attitudes toward mathematics and strategies for learning should be further explored.

STUDENT ATTITUDES

In this section, I will review the literature on student attitudes about mathematics, as well as what has been shown to change attitudes and how they are connected to mathematical content knowledge.

What is meant by the word "attitude"?

The word "attitude" can reflect many different notions, both positive and negative – particularly when associated with learning mathematics. It is therefore crucial to identify exactly what is meant in this dissertation by the word "attitude". Di Martino and Zan (2011) noted that in recent research, the "area investigating the interplay between cognitive and emotional aspects in mathematics education is known as *affect*", and that many researchers in the field see the affective domain as divided into *beliefs, attitudes, and emotions*, with others also adding a fourth category: *values* (p. 471). However, each researcher generally gives a definition about the specific meaning of the word "attitude" within the context of his or her research. Mitchell (1999), for example, defined "'negative' attitudes as those beliefs which indicate a lack of motivation, interest and enjoyment in mathematics" (p. 1). Laursen et al. (2011) categorized "attitudes" as "students' mathematical beliefs, motivation and strategies for learning and problem-solving" (p. viii). Thus, data collection will focus specifically on these aspects. However, the purpose of this section of the literature review is to use prior research to support both the idea that student attitudes can be changed and the claim that student attitudes are connected to content knowledge goals, in addition to giving examples of what has been shown to change attitudes within the classroom. Cited research may, therefore, include varying ideas of how the word "attitude" is defined, and may also use other terms such as "affect" to describe notions similar to those explored in this dissertation.

Evidence that attitudes can change

Many educational researchers have recognized the need for students to have a more positive attitude toward mathematics and a better understanding of how mathematics will be useful to them later in life. The National Action Council for Minorities in Engineering, Inc. (Gilroy, 2002) even created a national public service campaign entitled "Math is Power", which was aimed at improving student attitudes and beliefs about the importance of math and science. The follow-up research showed that student attitudes were, indeed, affected by this campaign. However, it remains important to consider what instructors can do within the classroom to change student attitudes about mathematics.

In the previously mentioned paper by Mitchell (1999), the focus was changing teaching methods with the goal of removing some of the negativity surrounding mathematics. To measure student attitudes, Mitchell used an oral survey with ten Likert scale questions and five open-ended questions. When analyzing the initial surveys, Mitchell noticed that the students were lacking motivation to achieve in mathematics and suggested one reason for this: "they failed to see a relevance between school maths [sic] and what they would need to know when they left school" (p. 2). Mitchell also noticed that students did not seem to associate mathematics with enjoyment, did not see mathematics as relevant, and "that students were not receiving appropriate feedback or engaging in positive evaluation procedures" (p. 2). As a result of these findings from the initial oral surveys, Mitchell implemented strategies to improve motivation, increase enjoyment, and involve students in their evaluation. Throughout the implementation, Mitchell collected data using observations, checklists, and discussions. After nine weeks of implementation, the results indicated positive changes in student attitudes toward math.

Sparrow and Hurst (2010) have also suggested that changes in a child's mathematics learning environment can lead to improved attitudes. Specifically, the authors suggested making the student experience more student-centered and using formats (such as games) that are more enjoyable. They stated that "employing simple planning techniques, such as adding variety, being clear about the purpose of any activity in mathematics, and ensuring success may lead to more children experiencing positive emotional reactions to their encounters with mathematics in primary classrooms" (p. 23).

On a wider scale, an analysis of data from an extended version of the international Trends in Mathematics and Science Study (TIMSS) of 2003 focused on three aspects of students' mathematics attitudes and how those aspects were affected by their learning environment (Vandecandelaere, Speybroeck, Vanlaar, Fraine, & Damme, 2012). The three aspects of the mathematics attitude were: 'mathematics academic self-concept', 'enjoyment of mathematics', and 'perceived value of mathematics', while the four dimensions in the learning environment were "the extent to which the teacher 'motivates to exert learning effort', 'activates toward self-regulated learning', 'gives feedback and coaches', and 'structures and steers'" (p. 1). Data analysis found that one aspect of mathematics attitude, enjoyment of mathematics, was affected by the learning environment.

Researchers have even studied the effects of a specific element of the classroom, such as the use of calculators. Ellington (2003) provided a thorough meta-analysis of 54 research studies aimed at determining the effects of calculator use on both student attitudes and achievement levels. Criteria for including a particular study were as follows: (1) the study was published between January 1983 and March 2002; (2) the study featured the use of a basic, scientific, or graphic calculator; (3) the study involved students in a mainstream K-12 classroom; and (4) the report of findings provided the data necessary for the statistical analysis. Rigorous statistical analysis allowed Ellington to conclude that students who used calculators had better attitudes than those who did not. Curtis (2006) also noted a similar effect in community college students, thus it stands to reason that calculators may indeed have an effect on student attitudes at all levels.

In a study of 600 high school students, Hoang (2008) investigated different factors such as grade level, gender, ethnicity, and the nature of the classroom environment and how these factors might affect attitudes toward mathematics. The researcher found "strong evidence of associations between students' attitudes and the learning environment" in addition to small differences between ethnic groups on the attitude scale (p. 48). Specific predictors of various aspects of individual student attitudes included: student cohesiveness, involvement, cooperation, equity, investigation, teacher support, and task orientation. Hoang further suggested that more research should be done on how to create a mathematics classroom environment that students perceive as positive.

Another study examined the effects of location and learning environment on students' attitudes toward statistics. Participants were undergraduate students located in both the United States and Zimbabwe who were enrolled in an introductory college statistics course. Mvududu found that "a constructivist environment was found to be significantly related to students' attitude toward statistics" (p. 1). Additionally, it was noted that there were significant differences in students' attitudes due to the differing locations of the groups.

Pepin (2011) also examined students from two different countries (Norway and England) and qualitatively analyzed their attitudes about mathematics based on the framework of Zan and Di Martino (2007). Through this analysis, Pepin was able to identify seven themes that were related to students' emotional disposition toward mathematics, their perception of whether or not they can be successful at mathematics, and their perception of what mathematics is:

> (1) Mathematics for jobs and 'later life'.
>
> (2) Mathematics is interesting, but hard and challenging for some, and boring and frustrating for others.
>
> (3) Repetitive nature of mathematics in classroom lessons.
>
> (4) Importance of working in groups (also for thinking) and support of friends.
>
> (5) The role of the teacher.
>
> (6) The support of the family and primary school for being able to do mathematics.
>
> (7) Examinations play an important part, both in terms of individual success as well as what doing mathematics means. (p. 7)

Several of these themes, namely "Importance of working in groups… and support of friends" and "The role of the teacher" are important to the research in this dissertation. As will be outlined in more detail in the next section of this literature review, these two themes are generally seen as components of the classroom that distinguish inquiry-based learning classrooms from traditional lecture classrooms.

Group work, or collaborative learning, appears again in a Townsend and Wilton (2003) study of 141 undergraduate students studying statistics and research design. This study was aimed at assessing whether traditional pre- and post-tests measuring students' mathematics self-concept and mathematics anxiety would indicate positive changes in mathematics attitude during a course that included large amounts of cooperative learning.

The data indicated significant positive changes between pre- and post-test attitudes, showing that collaborative teaching groups can affect student attitudes in a positive way. These findings corroborated an earlier meta-analysis of research done in undergraduate science, math, engineering, and technology from 1980 to 1999. In this meta-analysis, Springer, Stanne, and Donovan (1999) identified more favorable attitudes toward learning as one of the effects of small-group learning.

One last piece of evidence indicating that attitudes can be changed through instructional methods is a study of 70 students at a Saudi Arabian university. Yushua (2006) found that students who were in a class that used a blended e-learning program had significantly better attitudes toward computer use than they did at the beginning of the course. This is a key piece of research indicating that exposure to and familiarity with a particular component of a course can lead to better attitudes about that component.

Clearly, there is a growing body of research indicating that student attitudes can be changed by a variety of factors, including: classroom strategies specifically aimed at improving attitudes and enjoyment, learning environment, students' perception of the learning environment, calculator use, location of the course, working in groups, the role of the teacher, an enjoyable student experience, cooperative or collaborative learning, and even a media campaign.

Evidence that attitudes are connected to mathematical content knowledge and problem-solving

In addition to research which suggests that attitudes can be changed by various factors, there is a well-established body of research regarding how students' attitudes about mathematics are connected to content knowledge and problem-solving ability. This fact makes the quest to understand the factors that improve student attitudes even more crucial. Over 40 years ago, Aiken (1970) documented numerous examples of studies linking high school students’ attitudes toward mathematics and academic achievement. Pajares and Miller (1994) examined the role that "self-efficacy beliefs" played in 350 undergraduate students' mathematical problem solving. Basing their work on the definition of self-efficacy from social cognitive theory as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (Bandura, 1986, p. 391), the researchers found that math self-efficacy was a stronger predictor of mathematical problem solving than math self-concept, perceived usefulness of mathematics, prior experience of mathematics, or gender. More recent research continues to show that student attitudes toward mathematics influence their mathematical ability and problem-solving skills.

For example, Liu (2010) investigated how students with varying epistemological beliefs about mathematics performed on several types of assessments. The study was very small, with only four students. Two of the students “expressed a sophisticated belief that mathematical thinking is a logic-based, creative, and dialectical process involving guessing, testing, proving, and generalizing” while the other two “viewed mathematical thinking as an activity of solving arithmetical problems via implementing numbers and formulas” (p. 19). The students with more sophisticated epistemological beliefs performed significantly better on the standardized problems and problem-finding tasks, while results were not as clear on the semi-open homework problems. Given the sample size and mixed results, more research is needed to understand the exact relationship between epistemological beliefs and mathematics performance. However, this introductory study did indicate that the two are connected.

Panaoura, Gagatsis, Deliyianni, and Elia (2009) added further to our knowledge with a study of 1701 students in grades five through eight. The researchers developed a Likert-type questionnaire aimed at “measuring students’ beliefs about the use of different types of representations for understanding the concept of fractions" and a separate "test for measuring students' mathematical ability on multiple representation flexibility as far as fraction addition is concerned" (p. 716). Both were administered to the students at the end of the school year, and results indicated a strong interrelation between students' beliefs about multiple representation flexibility and their mathematical problem-solving abilities.

Students' beliefs about their likelihood of success in mathematics have also been linked to future enrollment in advanced mathematics classes. In a study of high school seniors, Rethinam (2004) found that how likely a student thinks he or she is to succeed in an advanced mathematics course affects whether or not they enroll in such a course, as does how successful the student was in previous courses. While this study did not measure mathematical content knowledge itself, it stands to reason that enrolling in an advanced mathematics course as a senior in high school would make a student more likely to enter college with more mathematical content knowledge. In a case study of an introductory Real Analysis course at the undergraduate level, Weber (2008) also noted that feelings of frustration and anxiety in a student led to the student placing more of an emphasis on rote learning strategies, while even small learning successes led to positive feelings toward mathematics and a desire to study the subject further.

In addition to studies which link specific attitudes about mathematics to mathematical content knowledge and motivation, several key studies link general beliefs about intelligence to learning successes. Using a framework established by Dweck and Sorich (1999), Mangels, Butterfield, Lamb, Good, and Dweck (2006) further investigated the findings by Elliot & Dweck (2005) which linked beliefs and learning success. More specifically, that "those who believe intelligence is a fixed entity" are not as successful as "students who believe intelligence is malleable", and furthermore that these latter students are better able to rebound from negative feedback and failures (p. 75). Upon examining these two groups, the researchers found that students who believed intelligence is a fixed entity actually had more activity in the parts of the brain that are connected to proving one's ability to others and less activity in areas of the brain that effect long-term memory (Mangels et al., 2006).

The wide range of research associated with attitudes and their effects on content knowledge, problem-solving ability, and even future enrollment in mathematics courses certainly indicates that attitudes about mathematics play an important role in mathematics education. It is a role that needs to be examined further at the community college level. In particular, the connections between student attitudes and teaching strategies should be explored.

INQUIRY-BASED LEARNING

In the next section of this literature review, I will examine the components of inquiry-based learning that might be expected to change student attitudes and review research findings which indicate that inquiry-based learning has been shown to have positive effects on students' content knowledge and attitudes.

What are some defining components of inquiry-based learning?

Inquiry-based learning is a phrase that is often used to mean a variety of teaching methods. A pivotal exposition of the ideas underlying such methods is found in the educational research report *How People Learn* (National Research Council, 2000). The report introduced the concept that teaching strategies should incorporate some levels of metacognitive activities. Such strategies are a form of inquiry-based teaching given that they often involve students questioning their own comprehension along with other students' ideas and solutions. Evaluating and monitoring self-progress is also a desired characteristic among students. In addition, inquiry-based methods "engage learners as active participants in their learning" by teaching students metacognition skills (p. 68).

The National Academy of Sciences (Committee on Development of an Addendum to the National Science Education Foundation Standards on Scientific Inquiry, 2000) identified five essential features that define an inquiry classroom. Learners must: (a) be engaged by scientifically oriented questions; (b) give priority to evidence; (c) formulate explanations from evidence; (d) evaluate their explanations in light of alternative explanations; and (e) communicate and justify their proposed explanations (p. 25). While these features are given in reference to a science classroom, similar characteristics exist in both national and state mathematics education standards, which will be discussed in the following paragraphs (National Council of Teachers of Mathematics, 2000; The Texas Education Agency, 2009).

In Principles and Standards for School Mathematics, the NCTM (2000) suggested that teachers should strive to create classrooms of inquiry that challenge students to create, discuss, and critique explanations and conjectures. The NCTM also proposed that students should be able to create, develop, and evaluate mathematical proofs in grades 9-12, and that this may be encouraged through inquiry-based learning. During a study of the influence of inquiry-based mathematics on 11th grade students, Chin, Lin, Chuang, and Tuan (2007) stated that essential traits of inquiry-based learning are "connecting former knowledge and experiences with the problems learners have, designing procedures (plans) to find an answer to the problem, investigating phenomena through conjecture, [and] constructing meaning through use of logic and evidence and reflection" (pp. 129-130).

Instructors who use inquiry-based methods have been able to create classrooms which look markedly different than those of their colleagues who employ more traditional, direct instruction methods (Laursen, Hassi, Hunter, Crane, & Kogan, 2010). Although each researcher has his/her own definition of inquiry-based learning, a general sense of the components focused on throughout this dissertation can be obtained from the descriptions above.

Results from literature

This section will compile results in educational research that have been found while studying inquiry-based learning environments. These results are divided into two sections: content knowledge and student attitudes. Both will be reviewed with regard to mathematics education as well as to other disciplines. The purpose of including other disciplines is to give an idea of the scope of influence of inquiry-based learning.

Content knowledge outcomes

Perhaps one of the largest studies investigating inquiry-based teaching methods involved over 6,000 students in 62 introductory physics courses. The results showed that students who were taught using "interactive-engagement" methods had an average gain that was almost two standard deviations above that of students using "traditional" methods (Hake, 1998).

In addition, an investigation of an inquiry-based physics curriculum which “centers around a metacognitive model of research, called the Inquiry Cycle, and a metacognitive process, called Reflective Assessment, in which students reflect on their own and each other's inquiry” revealed very interesting data (White & Frederiksen, 1998, p. 1). Sixth through ninth grade students who were taught using this curriculum outperformed eleventh and twelfth grade students on an assessment that measured physics knowledge.

The data from other disciplines is supported by a number of studies which show increased mathematical content knowledge related to inquiry-based teaching methods. Siegel, Borasi, & Fonzi (1998) found that reading, in conjunction with writing and talking, can serve to further students' understanding of mathematical ideas through inquiry-based activities. In addition, a six month study of teaching and learning mathematics in a classroom of fifth-grade students provided evidence that through inquiry-based teaching methods, students can grow closer to acquiring the type of mathematical thinking and knowledge that mathematicians use on a daily basis (Lampert, 1990). This research is corroborated by a more recent finding that inquiry-based mathematics teaching methods increase students' potential to solve problems as well as give them new problem solving strategies (E. T. Chin, Lin, & Wang, 2009).

Researchers have also noted at the undergraduate level that while students who were enrolled in an inquiry-based differential equations class were better at solving conceptually oriented problems, there was no statistical difference between the two groups of students on procedurally oriented problems (despite the fact such problems were the focus of the traditional classes). A follow-up study one year later also yielded similar results, indicating that an inquiry-based learning experience may have lasting effects on students' conceptual understanding (Kwon, Allen, & Rasmussen, 2005; Rasmussen, Kwon, Allen, Marrongelle, & Burtch, 2006). This is a key study because it indicates that while a difference between traditional and inquiry-based students' performance on procedural questions may not be present, conceptual understanding could still differ between the two groups.

Outcomes regarding student attitudes

Research has shown that student attitudes are related to achievement levels, thus it stands to reason that it is worth examining the effects of inquiry-based teaching methods on student attitudes (Southwell, White, Way, & Perry, 2005). In biology classes, Rivers (2002) found that students who were taught in an inquiry-based format appeared to enjoy learning more and were more motivated to learn than students taught using more traditional methods. This complements the findings of Chin et al. (2009), which revealed that using inquiry-based teaching strategies can have a positive effect on students' mathematics anxiety. The researchers in this study used a Math Anxiety Questionnaire at three intervals throughout the data collection period to supplement video tapes, student interviews, and instructor and student reflective journals. Inquiry-based learning has also been shown to increase student attentiveness and decrease frustration among elementary-aged mathematics students (Fielding-Wells & Makar, 2008).

Several other key components of inquiry-based learning have been connected to student attitudes. Mitchell (1999) found that developing students' communication skills can lead to improved student attitudes. She also attributed some of the changes in attitude to purposeful changes in the classroom environment. Springer et al. (1999) also found that greater academic achievement and increased persistence through science, math, engineering, and technology courses and programs (in addition to more favorable attitudes toward learning) were effects of small-group learning formats.

Finally, the Laursen et al. (2011) study examined the effects of inquiry-based learning (IBL) on undergraduate students enrolled in a mathematics course at several four-year universities. While the changes in beliefs, motivations, and strategies were modest for both IBL and non-IBL students, there was evidence to suggest that the two types of courses had opposite effects in the areas of confidence and collaboration. IBL students had mostly positive effects for these areas, whereas most of the changes in the non-IBL courses were negative effects. For example, students in non-IBL classes tended to lose confidence in their ability to do mathematics whereas their IBL counterparts did not. Additionally, students enrolled in IBL courses showed an increase in their beliefs of the importance of collaborative strategies such as working in groups and effectively communicating mathematics to others. By using the same attitudinal survey as this study, I will be able to compare the results of IBL teaching methods on the community college population to those published by Laursen et al.

Inquiry-based Learning in Practice

While positive effects of inquiry-based learning have been noted in research, the implementation of such teaching practices does not come without difficulties. Teachers hold diverse beliefs about inquiry-based learning. Chan (2010) found that the variation in these beliefs impacted teachers' implementation of inquiry-based learning. This issue must not be ignored when considering the difficulties of large-scale implementations of inquiry-based teaching strategies. Moreover, it has been noted in science classrooms that teachers use different strategies for selectively answering student questions while students are exploring a new idea. Developing the skills to cope with demands of inquiry-based learning can take time. Furtak (2006) documented that teachers' strategies included creating a game-like atmosphere during the investigation, accepting students' ideas without evaluation, and spending time rationalizing pedagogical decisions to students.

Beyond acquiring new skills for guiding students during investigation, the implementation of lessons involving inquiry and/or project-based instruction often requires teachers to develop new lessons and adopt new technology (Rogers, Cross, Gresalfi, Trauth-Nare, & Buck, 2011). Moreover, these struggles are complicated by the need to ensure that academic standards are met and prepare students for standardized exams. Rogers et al. (2011) described the experience of a teacher who abandoned his new inquiry-based teaching approach mid-year and returned to more traditional drill and practice methods because he concluded that it was necessary for teaching mathematics skills.

Conversations in teachers' lounges at all levels confirm that concerns about content coverage are not uncommon. Schwartz and Bransford (1998) presented an argument that student learning from texts and lectures can be made more effective if they have first "had an opportunity to generate well-differentiated knowledge about a domain" (p. 476). The idea that inquiry-based learning could be used to create an appropriate "time for telling" may be well suited for the community college environment where instructors typically have only three or four hours of contact time with their students each week. As will be later seen in the data collected for this dissertation, many instructors already use a mixture of lecture and inquiry-based learning strategies.

CONCLUSION

The problems associated with remedial community college education are complex. However, there is ample evidence from educational research literature to warrant investigating the effects of inquiry-based learning on both mathematical content knowledge and student attitudes about math. Perhaps the incorporation of inquiry-based components will form a piece of a solution to the problems outlined in this literature review.

Chapter Three: Methodology

PURPOSE

The purpose of this study is to investigate the relationships among teaching methods, student attitudes, and content. Thus, the research questions are:

1. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' attitudes about math?
2. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' mathematical content knowledge?
3. Are community college students' attitudes about mathematics connected to their mathematical content knowledge?

PARTICIPANTS

Participants for this study were enrolled at a large urban community college with eight main campuses. As an instructor myself, I was able to recruit colleagues who agreed to allow me to collect surveys and assessments from their students. Data collection began in the Spring semester of 2012, with nine instructors who taught a total of eight sections of Basic Math Skills and four of College Algebra. Some instructors had only one section from which data was collected, while others had several. Data was collected from an additional two sections of College Algebra (from one instructor) during the Summer semester of 2012 and three sections of College Algebra (from three instructors) during the Fall semester of 2012.

Instructor experience varied among the instructors. A noticeable difference in teaching experience was that the lecture instructors had more community college and K-

12 experience on average. *Table 3.1* reports each instructor's teaching experience, highest degree obtained, and how many years (if any) the instructor had been incorporating student-led activities.

Teacher ID	Instruction Method	Years of Experience Teaching			Highest Degree Obtained	Degree Field	Years Incorporating Student-led Activities
		Community College	University	K-12			
3970	Lecture	11	0	12	Bachelor's	Engineering	n/a
3973	Lecture	22	0	43	Bachelor's	Mathematics	n/a
3979	Lecture	21	5	0	Doctorate	Mathematics	n/a
3996	Lecture	3	6	0	Doctorate	Mathematics	n/a
4010	Lecture	23	5	0	Master's	Mathematics	n/a
	Lecture Averages:	**16**	**3**	**11**			
3977	Student-led	17	0	31	Bachelor's	Biology	5
3989	Student-led	3	2	0	Doctorate	Mathematics	2
3998	Student-led	15	0	0	Doctorate	Math Education	6
4000	Student-led	7	2	0	Master's	Mathematics	4
4002	Student-led	3	3	1	Doctorate	Mathematics	3
	Student-led Averages:	**9**	**1**	**6**			**4**

Table 3.1. Instructor experience.

Basic Math Skills is the lowest level developmental course offered in the mathematics department of the community college. Students placed into the class must pass two more developmental courses in addition to Basic Math Skills before meeting the prerequisite necessary for a college-level mathematics course. College Algebra is a credit-bearing course at this community college, but the content essentially replicates high school Algebra I and II. As a result, many students have seen the content prior to enrolling in the course. These two classes were chosen for several reasons. First, one goal of this research is to compare the survey results of community college students to those of a previous study conducted at several large research universities. Second, I have seen some success at incorporating what I refer to as "student-led activities" into these courses while teaching them myself, and I have colleagues who have done the same. Thus, these particular courses were fairly convenient to access and I had several colleagues who were willing to allow data collection in them. Finally, I wanted to have at least two different courses that would illustrate students' algebraic content knowledge. These reasons led me to focus my research on Basic Math Skills and College Algebra.

The demographics of the community college for enrollment during the Spring semester of 2012 are summarized below. *Table 3.2* shows the demographics of the entire community college, whereas *Table 3.3* shows only the students enrolled in developmental mathematics courses (Office of Institutional Effectiveness and Accountability, 2012). Note that College Algebra is not considered a developmental course, so College Algebra students are included in the headcounts from *Table 3.2* but not *Table 3.3*.

The data for this dissertation was collected from 270 individual students. *Table 3.4* summarizes the demographic data collected from these students. The percentages from this table for gender are similar to those in *Table 3.2* and *Table 3.3*. Additionally, the race/ethnicity percentages in *Table 3.4* for the largest four categories (white, black, Hispanic, and Asian) fall between the percentages in *Table 3.2* and *Table 3.3.* Since the study involves both developmental mathematics students and non-developmental mathematics students, this indicates that the gender and race/ethnicity characteristics of the sample are similar to the overall community college population.

Before data collection began, I gained approval from the Institutional Review Board at The University of Texas as well as the body that governs research at the community college. By consenting to the study, students agreed to allow the use of their surveys and any assessments given during class for research purposes. Once consent forms were matched with surveys and final exams, students were assigned a participant identifier and names and all identifying personal information (such as email addresses) were removed from the database.

Student Headcount		44,425	
Gender	Male	19,768	44.50%
	Female	24,657	55.50%
Student Status	Part-time	34,929	78.62%
	Full-time	9,496	21.38%
Race/Ethnicity	White	21,779	49.02%
(students were counted in only one category)	Black	3,774	8.50%
	Hispanic	12,064	27.16%
	Asian	2,054	4.62%
	Hawaiian/Pacific Islander	55	0.12%
	Am. Indian/Alaskan Native	352	0.79%
	Non-Resident Alien	1,039	2.34%
	Two or more	530	1.19%
	Other/Unknown	2,778	6.25%

Table 3.2. Community college demographic data.

Student Headcount		8,124	
Gender	Male	3,562	43.85%
	Female	4,562	56.15%
Student Status	Part-time	6,073	74.75%
	Full-time	2,051	25.25%
Race/Ethnicity (students were counted in only one category)	White	3,035	37.36%
	Black	1,147	14.12%
	Hispanic	2,867	35.29%
	Asian	158	1.94%
	Hawaiian/Pacific Islander	14	0.17%
	Am. Indian/Alaskan Native	61	0.75%
	Non-Resident Alien	192	2.36%
	Two or more	91	1.12%
	Other/Unknown	559	6.88%

Table 3.3. Community college demographic data, developmental mathematics only.

Student Headcount		270	
Gender	Male	118	43.7%
	Female	136	50.4%
	Missing	16	5.9%
Race/Ethnicity (students were counted in only one category)	White (non-Hispanic)	109	40.4%
	Black	28	10.4%
	Hispanic	91	33.7%
	Asian	9	3.3%
	Am. Indian/Alaskan Native	4	1.5%
	Two or more/Other	12	4.4%
	Missing	17	6.3%

Table 3.4. Participant demographic data.

INSTRUMENTS OVERVIEW

Data was collected using three instruments: attitudinal surveys, final exams, and classroom observations. All instruments can be found in Appendix A.

The attitudinal survey was used to measure seven aspects of the students' experiences in a mathematics course: (1) interest in mathematics, (2) enjoyment of mathematics, (3) mathematical goals, (4) strategies for learning mathematics, (5) preferences for learning mathematics, (6) strategies for solving problems, and (7) confidence in doing mathematics. The reliability of these constructs is reported in *Table 3.7*. The survey questions were based on a survey developed by Laursen, Hassi, Kogan, Hunter, and Weston (2011). The Laursen et al. study focused on undergraduate students, while the present study focuses on students at a community college. Therefore, a few of the questions were modified or excluded because of this difference in population (for example, questions about what constitutes a mathematical proof were not relevant to the community college population as proofs are not included in the curriculum). In addition to collecting information about the above constructs, the survey also collected self-reported student background information such as age, gender, ethnicity, race, high school and college GPA, and parent education levels. The survey took approximately 15 minutes to administer. In six sections of College Algebra, the surveys were collected online through SurveyMonkey due to time constraints in the classroom. I ran independent *t*-tests on each composite attitudinal variable to compare the survey results that were collected online to the survey results collected during class. There were no significant differences for any of the 17 composite means, indicating that students responded to the two formats in similar ways.

Final exams were collected for all students who consented to the study and were still enrolled at the time of collection. In Basic Math Skills classes, all instructors gave the same final exam. There were two versions of the exam, but they were identical in concept (with small variations to help control for dishonesty). The individual instructor had discretion as to whether or not he or she used one or both versions of the final. College Algebra instructors write their own final exam. I identified five common questions on the

College Algebra final exams. Analysis of the final exams will be discussed in detail in the data analysis section of this chapter.

Finally, classroom observations were completed for each course. Using a slightly modified version of the observation protocol used by Laursen et al., a colleague and I observed each class during the middle of the semester. We recorded a general description of each classroom which included notes on class context, student population, interactions, mood, morale, etc. We also categorized the main activities throughout the class. Activities recorded include lecture, explaining, group work, student presentations, class business, individual work, homework question and answer, and quiz or other assessment.

OBSERVATIONS

Observation Protocol

While the observation protocol was based on one developed for a previous study by Laursen et al. (2010), a few slight adjustments were necessary in order to better document the community college classroom. I, together with a colleague who had previously been trained to use the Laursen et al. protocol, developed detailed descriptions allowing differentiation between classroom activities. Using these descriptions, we observed four classes together and compared our observations to ensure that we categorized the main classroom activities in the same way. There were very few discrepancies, and in all cases we were able to resolve how to categorize the activity in question. Additionally, I performed an interrater reliability analysis using SPSS to calculate the Kappa statistic on how each minute of class was categorized. The interrater reliability for the raters was found to be Kappa = 0.933 ($p < 0.001$), 95% CI (0.892, 0.974). This is generally considered "almost perfect agreement" (Landis & Koch, 1977). The resulting observation protocol is given in Appendix A and was used to observe each class throughout the semester, with the main goal being to categorize each class as either "lecture" or "student-led". Using the observations for this purpose differs from the previous study, where classes were identified as being "IBL" or "non-IBL" by both the instructors and the institutions prior to the start of the study.

Summary of Observation Data

Using the observation data, I was able to calculate the portion of class time spent on "lecture", "homework question and answer", or "explaining" (referred to as "instructor-led activities") and compare this to the portion of class time spent on "discussion", "presentations", or "group work" (referred to as "student-led activities"). Classroom activities such as class business or assessment were not considered to be in either category (instructor-led or student-led), thus the percentages do not necessarily add up to 100%. *Table 3.5* gives these percentages for 13 out of 17 sections included in the study. We were unable to observe the remaining four sections, but as they were taught by the same instructors (and in the same style) as other student-led sections by those same instructors, they were classified as student-led.

Based on the observation data, I chose to classify sections where 40% or more of class time was spent on "student-led activities" as "student-led", and the remaining sections as "lecture". Ideally, I would have liked to classify sections such as 6528, 6500, and 6512 as a mixture of "student-led" and "lecture". As outlined in the literature review, it would be worth investigating the role that inquiry-based activities play in preparing students to acquire information from a lecture. However, due to the small study size this would have further limited the statistical analyses. Completed observation protocols and a more detailed breakdown of classroom activities for each section are provided in Appendix B.

Course Title	Section ID	Instructor Led Activities	Student-Led Activities	Instruction Method
College Alg.	6545	75%	0%	Lecture
College Alg.	6519	83%	0%	Lecture
College Alg.	6523	84%	0%	Lecture
Basic Math	6538	86%	0%	Lecture
Basic Math	6494	72%	11%	Lecture
Basic Math	6504	65%	15%	Lecture
Basic Math	6525	63%	0%	Lecture
Basic Math	6531	49%	0%	Lecture
College Alg.	6528	59%	40%	Student-led
Basic Math	6500	39%	50%	Student-led
Basic Math	6512	47%	40%	Student-led
Basic Math	6543	19%	78%	Student-led
College Alg.	6520	14%	82%	Student-led

Table 3.5. Observed classroom activities and resulting instruction method.

Classroom descriptions

Student-led

Sections that were classified as "student-led" clearly spent more time on activities that directly involved students. For the majority of class time, students did not have the option of sitting and listening. They were expected to participate and contribute, whether through group work, a discussion, or student presentations. Overall, a higher percentage of students were engaged with the mathematics content in these classes. The observation data indicated that for all student-led sections, between 75% and 100% of students participated during class. There was variation among the time spent on student-led activities, as can be seen in the chart above. Percentage of class time spent on student-led activities ranged from

40% to 82%. In the sections on the lower end, instructors typically spent more time lecturing or explaining problems.

Several instructors had classrooms that were informative examples of a student-led environment. Below, I give detailed descriptions of a typical class in both Basic Math Skills and College Algebra.

Basic Math Skills: Overall Impressions (Student-led)

The instructor clearly had well-developed relationships with the students. She knew their names and student morale was high. During class, she checked for understanding frequently. Students willingly participated throughout the class.

Basic Math Skills: Class Proceedings (Student-led)

Students spent the first ten minutes of class on an individual quiz. Following the individual quiz, students spent another ten minutes on a group quiz. During the group quiz, all of the students were participating and contributing to their group's progress on the quiz. Once the groups turned in the quizzes, the instructor asked for questions over homework and reviewed operations with decimals. During this time, the students interacted with the instructor and asked questions. The instructor also asked questions frequently, and most of the students were very responsive. One female student was particularly vocal, and the instructor managed this issue by calling on different students by name periodically.

After students had no more questions regarding the homework, the instructor spent about two minutes lecturing over new material. She then distributed instructor-designed worksheets which covered the new material. Students worked on these worksheets in groups of two or three. During this time, the instructor circulated the room clarifying questions and redirecting students as necessary. All of the students seemed to be working on the worksheet during this time. After about 40 minutes, the instructor brought the class together and spent about five minutes summarizing the content on the worksheets. Students asked questions during this time and were generally responsive to the instructor's questions. During the last fifteen minutes of class, the instructor introduced the content for the next section's worksheet and gave students a plan for completing it. She handed out another worksheet and then dismissed class.

College Algebra: Overall Impressions (Student-led)

The instructor in this class seemed to have a good rapport with the students. He was able to call on them by name during the class, and students responded well to him. Throughout the class, it was apparent that students were influencing the direction of how the material was handled. For example, one student asked the instructor to leave some information (properties of logarithms) on the board and put a box around it. The student later referred to the information during his presentation, as did several others. To me, this indicated not only that student input was valued and listened to, but that students had been honing their presentation skills and saw the value of having that information readily accessible.

College Algebra: Class Proceedings (Student-led)

The instructor began class by reviewing the meaning of logarithm with students. He asked them to write down the meaning of "$\log_3 7$" in a complete sentence. He then circulated the room while students wrote down their answers and followed up with a class discussion of the results. The instructor went on to pose a few more similar questions, making sure that students had a concrete understanding of the meaning of logarithm. He then discussed a few more logarithm examples and included several sets of examples (such as $\log_2 64$, $\log_2 16$, and $\log_2 4$) that led students to guess the product rule for logarithms. The instructor was at the board during this time, but the majority of what he wrote was dictated by students. He selected the important, pertinent information from students' ideas and recorded it on the board. This discussion went on for around ten minutes. The instructor then lectured over a few more logarithm rules for three minutes. Following the brief lecture, students worked in groups on worksheets, which the instructor had prepared, while he circulated the room. Students worked in groups for about 10 minutes, and during this time the instructor assigned problems for specific students to work on the board. Individual students presented problems on the board for about 20 minutes. During presentations, the class gave the student presenters feedback on their solutions. The instructor also commented on solutions, but he allowed for students in the audience to address their concerns first. After the presentations, the instructor ended class with a five minute lecture about how to graph logarithmic functions.

Lecture

Sections that were classified as "lecture" spent almost all of the instructional time on instructor-led activities. The observation data indicated that for half of the lecture sections, between 25% and 50% of the students participated during class. For the other half of the lecture sections, between 50% and 75% of the students participated. Typically, questions asked by an instructor were answered by the same student or handful of students. A few of the Basic Math Skills sections incorporated whole-class discussions or student board work, which accounted for the time spent on "student-led" activities that can be seen in the *Table 3.5*. While observing, we considered the instructors who used mostly instructor-led teaching strategies to have very clear, well-planned lectures. Below, I give examples of a typical class day in both Basic Math Skills and College Algebra.

<u>Basic Math Skills: Overall Impressions (Lecture)</u>

The instructor provided direct instruction in a meaningful way. The observer considered him a very good lecturer, and noted that students were not afraid to make mistakes when answering questions. The instructor listened and responded to student questions and comments. About one-fourth to one-half of the students participated throughout the class.

Basic Math Skills: Class Proceedings (Lecture)

The instructor began class by going through a quick review for about five minutes followed by two minutes of question and answer time. He then passed out a “quiz”, which he did not intend to collect. He told the students that he just wants them to work on it and see how they do. The students worked for about five minutes and then the instructor asked three of them go to the board and write up their solutions. Meanwhile, the other students continued working on their quizzes or looking at the solutions on the board. This only took two or so minutes. The instructor then led the class in a discussion about the quiz problems, which lasted about 10 minutes. Next, he asked for homework questions about another section and responded to students’ inquiries in an encouraging way. After about 10 minutes, he gave another “quiz” over this section and used the same process as before (students worked on the quiz, a few put solutions on the board, then the instructor went over the problems). The instructor spent the remaining 45 minutes of class lecturing over new material. This portion of class was conducted using direct instruction, but the instructor was careful to include many visual examples and cues for students to ask questions.

College Algebra: Overall Impressions (Lecture)

The instructor seemed to have a positive relationship with the students. When the instructor was at the board working homework problems or lecturing, only about one-half to one-third of the students seemed to be paying attention and taking notes. The instructor asked both low-level and deeper conceptual questions during the lecture. A small group of about five students answered most of the questions and asked occasional questions themselves.

College Algebra: Class Proceedings (Lecture)

The instructor started class by passing back graded quizzes then asking for questions over homework. He spent about ten minutes addressing students' homework questions by working out problems on the board. This was followed by a daily quiz which was open notes. During the quiz, which lasted 12 minutes, the instructor wrote a few formulas on the board that he later used during the lecture. Once the students had turned in their quizzes, he reviewed a few formulas from the last class. The instructor then lectured for the remainder of class (about 45 minutes) over compound interest. Overall, the instructor's lecture was well-organized and the board work was clear and easy to read.

Similarities

In both student-led and lecture sections, each instructor appeared to have a good rapport with his or her students. All seemed genuinely dedicated to helping the students learn, and they were willing to patiently answer questions whenever students had them. Most (but not all) instructors incorporated some degree of both student participation and lecture. This was particularly true in Basic Math Skills classes. Group work and students going to the board was present in almost all Basic Math Skills classes, even those who spent the majority of class time on instructor-led activities.

Differences

The clear difference between student-led and lecture sections was the amount of time the instructor spent lecturing or explaining. Additionally, student involvement and attentiveness was generally higher in student-led sections, as students were often the ones explaining or working a problem. These differences were especially present in the College Algebra classes. The lecture sections of College Algebra did not incorporate any student group work or presentations and spent most of the time in class on quizzes, lecture, and homework explanations. However, the student-led sections of College Algebra incorporated large blocks of time for group work and student presentations.

DATA ANALYSIS

Introduction

For this dissertation work, I analyzed the surveys and final exams collected throughout the Spring, Summer, and Fall semesters of 2012. A complete data analysis is given in Chapter Four: Results. In the remainder of this chapter, I will outline the methodology of this analysis.

Participants by Course and Instruction Method			
	Student-led	Lecture	**Total**
Basic Math Skills	35	66	101
College Algebra	90	79	169
Total	125	145	**270**

Table 3.6. Summary of participants.

Table 3.6 shows the breakdown of the participants by course (Basic Math Skills or College Algebra) and Instruction Method (student-led or lecture). *Figure 3.1* shows the breakdown of the participants by which types of data were collected for each student. Some students were missing various components, either due to student absences or difficulties collecting that particular piece of data (such as an instructor who ran out of class time and did not allow for post-survey collection).

As can be seen in *Figure 3.1*, of the 270 total participants there are only 130 with all three pieces of data (pre-survey, post-survey, and final exam). Clearly, the sample size would be increased if such large numbers of students were not missing key pieces of data.

Methods for imputing missing data values as well as the decision not to proceed with imputation will be discussed below.

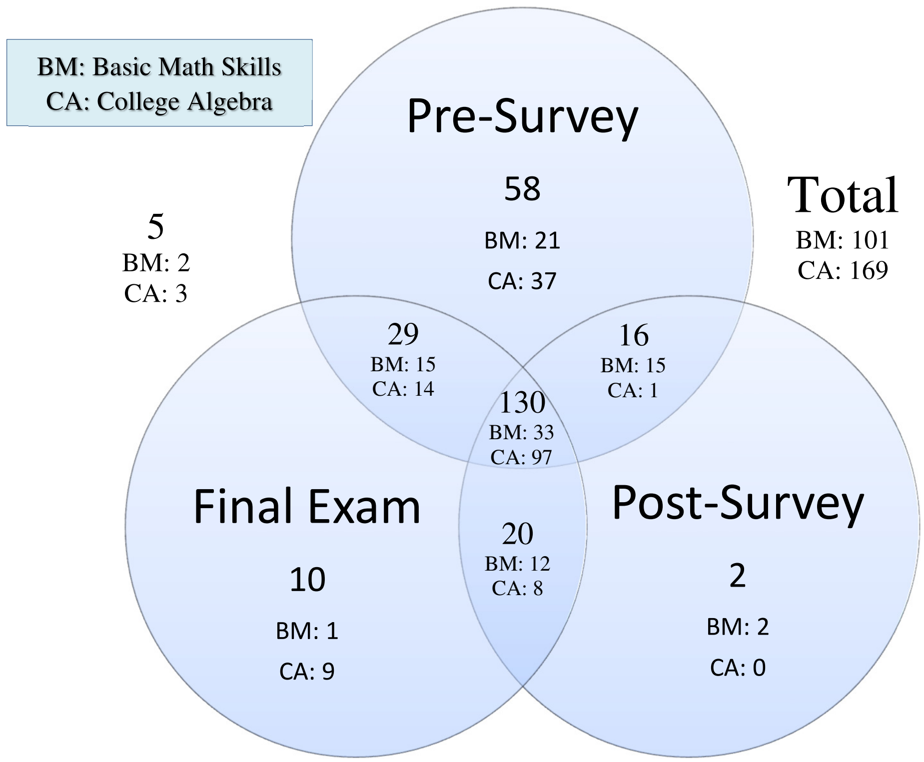


Figure 3.1. Counts of participant data obtained.

Attitudinal Survey Analysis

Attitudinal Variables

Using the results from the pre- and post-surveys, I created a set of composite "attitudinal" survey variables. In the previous study by Laursen et al., the researchers used exploratory factor analysis to group the survey questions into 20 composite variables. By using the corresponding survey questions from my own survey, I was able to create 17 composite attitudinal variables. The difference in the number of composite variables was a result of the population difference – my surveys did not include questions about being a mathematics major or beliefs on mathematical proofs. All questions were either identical to the original survey questions or slightly modified for the community college population. The breakdown of each of the 17 composite variables is shown in *Table 3.7* below.

Also reported in *Table 3.7* are the reliability scores of the composite variables (Cronbach's alpha). One of the 17 composite variables had a low reliability score (less than 0.7) on the pre-survey (*group work*), one had a low reliability score on the post-survey (*teaching confidence*), and two had low reliability scores on both the pre- and post-survey (*math future and practice*). Three of these four also had low reliability scores in the Laursen et al. study, indicating that these results are not unusual.

Variable	Description	Scale	Items		Reliability (Cronbach's alpha)	
			Count	Labels	Pre	Post
Motivation						
Interest	Interest in learning and discussing mathematics	7	2	1c, 1d	0.720	0.730
Math future	Desire to pursue math in future work or education	7	2	1a, 1b	0.420*	0.484*
Teaching	Desire to teach math	7	1	1f	--	
Enjoyment						
Enjoyment	Pleasure in doing and discovering mathematics	7	6	2a, 2b, 2c, 2d, 2e, 2f	0.901	0.943
Confidence						
Math confidence	Confidence in own mathematical ability	7	6	7a, 7b, 7d, 7e, 7f, 7g	0.874	0.893
Teaching confidence	Confidence in teaching math	7	2	7c, 7i	0.736	0.687*
Goals for studying math						
Intrinsic	Learning new ways to think & to apply math	7	4	3h, 3i, 3j, 3k	0.856	0.879
Extrinsic	Meeting requirements; degree, good grades	7	4	3a, 3c, 3g, 3d	0.779	0.791
Communicating	Communicating mathematical ideas to others	7	3	3b, 3e, 3f	0.825	0.826
Beliefs about learning						
Instructor-driven	Exams, lectures, instructor activities	7	4	5a, 5f, 5g, 5i	0.739	0.707
Group work	Whole-class or small group work	7	3	5b, 5c, 5e	0.687*	0.837
Exchange of ideas	Active verbal interaction with other students	7	3	5j, 5k, 5l	0.797	0.768

Table 3.7. Composite attitudinal variables.

Variable	Description	Scale	Items		Reliability (Cronbach's alpha)	
			Count	Labels	Pre	Post
Beliefs about problem-solving						
Practice	Repeated practice, remembering	7	2	6b, 6f	0.596*	0.374*
Reasoning	Rigorous reasoning, flexibility in solving	7	5	6a, 6e, 6g, 6h, 6i	0.704	0.752
Strategies						
Independent	Finding one's own way to think & solve problems	7	4	4e, 4i, 4k, 4l	0.799	0.829
Collaborative	Seeking help, actively sharing with others	7	3	4b, 4d, 4n	0.778	0.813
Self-regulatory	Planning, organizing, reviewing one's own work	7	6	4a, 4c, 4f, 4g, 4h, 4j	0.792	0.811

* indicates a low reliability score

Table 3.7, continued. Composite attitudinal variables.

Using each student's survey results, I calculated the 17 composite variables based on their average rating for each of the corresponding survey questions. This calculation gave each student 17 pre-survey attitudinal variables and 17 post-survey attitudinal variables. In the original study, the researchers first analyzed the pre-survey results to compare the groups of students at the beginning of the semester. They found differences in 15 out of 20 attitudinal variables. I, however, found differences among the pre-surveys of the four groups of students for only seven out of 17 attitudinal variables. Additionally, there were only four instances (all of which were in College Algebra) where student-led sections and lecture sections differed among the same course. There were no differences between the pre-survey means for student-led and lecture sections of Basic Math Skills. This discrepancy could be attributed to the prior study's larger sample sizes in addition to student self-selection (many students in the prior study knew whether or not they were enrolling in an IBL section, whereas students in the present study would most likely not have known in advance which sections would incorporate more student-led activities). *Table 3.8* shows the pre-survey means for each group of students and indicates which means were significantly different. Note that this table includes all students who completed a pre-survey, regardless of whether or not they completed a post-survey or final exam.

Average Changes in Beliefs, Motivation, and Strategies

Chapter Four reports the results of using paired *t*-tests on each group of students (A: Basic Math Skills – Student-led, B: Basic Math Skills – Lecture, C: College Algebra – Student-led, and D: College Algebra – Lecture). I ran a *t*-test for each of the 17 composite variables in each group to determine if there were any changes in survey responses. This analysis is included here (rather than in the results section) to verify that participants enrolled in student-led courses had similar attitudes to those enrolled in lecture courses at the start of the semester.

Comparison of Other Characteristics

In addition to comparing the incoming attitudes of student-led and lecture sections, I compared other key characteristics to determine whether or not there were differences between the two groups of students. For both courses, this comparison included an examination of the following self-reported survey information: high school GPA, college GPA, highest math class taken in high school, parent education levels, number of attempts in the current class, age, ethnicity, and gender. I also investigated the relationship between time of day and objective scores (objectives are described below in the Final Exam Analysis section). Additionally, for Basic Math Skills students I collected an arithmetic assessment used by many instructors at the community college to identify weaker students at the beginning of the course.

Attitudinal Variable		Average rating (7-point scale)				Sig. level (for each pairwise comparison)
		Basic Math		College Algebra		
		A Student-led (N = 30)	B Lecture (N = 37)	C Student-led (N = 49)	D Lecture (N = 42)	
Motivation	*Interest*	**2.2**	**2.3**	**3.4**	**2.9**	A,B<C***, D* D<C*
	Math future	**3.6**	**3.8**	**4.7**	**3.9**	A,B,D<C**
	Teaching	5.0	5.0	4.8	5.7	
Enjoyment	*Enjoyment*	**3.0**	**3.1**	**4.1**	**4.1**	A<C***,D** B<C***,D***
Confidence	*Math confidence*	**4.2**	**4.2**	**5.1**	**4.5**	A**,B***,D*<C
	Teaching confidence	**3.5**	**3.3**	**4.5**	**4.5**	A<C**,D** B<C***,D***
Goals	*Intrinsic*	5.4	**4.8**	**5.8**	**5.7**	B<C***,D***
	Extrinsic	5.9	5.9	6.2	6.2	
	Communicating	5.5	5.0	5.5	5.3	
Beliefs about learning	*Instructor-driven*	6.0	5.7	5.8	6.0	
	Group work	4.2	4.2	4.3	4.2	
	Exchange of ideas	4.2	**3.7**	**4.7**	4.2	B<C**
Beliefs about problem-solving	*Practice*	5.5	5.0	5.5	5.7	
	Reasoning	5.0	4.7	5.2	5.2	
Strategies	*Independent*	5.2	4.9	5.3	5.3	
	Collaborative	3.5	3.8	**4.0**	**3.2**	D<C**
	Self-regulatory	5.4	5.1	5.6	5.4	

$p < .05$, $p < .01$**, $p < .001$*** (according to Fisher's LSD test)*

Table 3.8. Average beliefs, motivation, and strategies at the start of the course.

Basic Math Skills

Using SPSS, I ran four *t*-tests on the arithmetic assessments given to Basic Math students at the beginning of the semester to compare the student-led and lecture sections. I compared the means of four operations between the groups. I found no statistical difference between the two groups for any of the operations: addition (p = 0.059), subtraction (p = 0.061), multiplication (p = 0.110), and division (p = 0.083).

Again using SPSS, I ran chi-squared tests of independence of categorical variables to determine if the background variables were independent from the instruction method. I was not able to reject the null hypothesis of independence on any of the background variables collected on the survey: high school GPA (p = 0.330), college GPA (p = 0.071), highest math class taken in high school (p = 0.896), mother's education level (p = 0.208), father's education level (p = 0.558), number of attempts in the current class (p = 0.417), age (p = 0.647), ethnicity (p = 0.382), and gender (p = 0.762). These results indicate that there were no differences between the two groups (lecture and student-led).

Start time	**Basic Math**		**College Algebra**	
	SL	**Lecture**	**SL**	**Lecture**
Before 10 am	0	1	0	0
10 am - noon	2	1	0	0
noon - 2 pm	0	1	1	1
2 pm - 4 pm	1	0	2	1
4 pm - 6 pm	0	1	1	1
After 6 pm	0	1	2	0

Table 3.9. Number of sections per time frame.

Finally, I used ANOVA to determine if there were content knowledge differences based on the time of day the class started. I categorized classes into six start time categories: prior to 10 am, 10 am to noon, noon to 2 pm, 2 to 4 pm, 4 to 6 pm, and after 6 pm. *Table 3.9* shows the breakdown of how many student-led and lecture classes were in each time frame. There were no significant differences for objective one (p = 0.057), objective two (p = 0.391), objective three (p = 0.425), objective five (p = 0.091), objective six (p = 0.434), objective seven (p = 0.285), or objective eight (p = 0.106). The only statistically significant difference among the groups was the “after 6 pm” category, which scored significantly lower than all other time frames on objective four ($p = 0.002$). Since the “after 6pm” category included only one section, it is not clear if this difference was due to instructional method or time of day.

College Algebra

I performed a similar analysis for College Algebra with the exception of the arithmetic assessments (which instructors typically do not give in College Algebra). I was again unable to reject the null hypothesis of independence using a chi-squared test for each of the survey background characteristics: high school GPA ($p = 0.829$), college GPA ($p = 0.256$), highest math class taken in high school ($p = 0.805$), mother’s education level ($p = 0.978$), father’s education level ($p = 0.928$), number of attempts in the current class ($p = 0.897$), age ($p = 0.916$), ethnicity ($p = 0.400$), and gender ($p = 0.488$). These results indicate that there were no differences between the two groups (lecture and student-led).

Using ANOVA and the same time frames in *Table 3.9*, I did not find any differences for objectives one ($p = 0.112$), three ($p = 0.293$), or five ($p = 0.248$). For objective two, students in the 2-4 pm category had significantly higher scores than students in all other time frames ($p < 0.001$). Two of these sections were student-led and one was lecture. Additionally, for objective four, students in the 4-6 pm category had significantly lower scores than students in all other time frames ($p < 0.05$). One of these sections was student-led and one was lecture.

Conclusion

Based on the above analysis, we can rule out the aforementioned background characteristics as a cause for differences seen during the complete analysis (given in the Chapter Four). The few differences seen in time of day are inconclusive.

Decision not to Impute Missing Values

One issue that arose during this dissertation work was the problem of missing values. Out of 233 participants with pre-survey results, only 146 also had post-survey results. I considered using students' final exam results in addition to student background data to impute the missing post-survey values by using multiple imputation (Puma, Olsen, Bell, & Price, 2009; Rubin, 1996). However, upon inspecting the data set it seems that only 29 of the 87 students who were missing post-survey results had final exams that were collected. This would add an average of only seven students to each of the four groups. Additionally, as will be discussed in Chapter Four, the final exams were not found to be very highly correlated to the survey results. Therefore, given the small overall impact and minimal final exam link to the survey results, I decided not to impute the missing values.

Final Exam Analysis

Basic Math Skills

Objectives

The final exams for the Basic Math Skills class were uniform across all sections. This conformity makes comparison across the classes fairly straightforward. While the questions are all the same, each instructor is responsible for creating his or her own grading scheme for the exam. Thus, it was necessary to analyze the student work itself rather than use the instructors' scores for the exams. The goal of the analysis was to give each student a score for eight skills or concepts that recur throughout the exam (referred to as objectives). In order to obtain these objectives, I first took each problem on the final exam and wrote down the skills needed to successfully complete the problem. For example, one problem asks students to "perform the operations indicated":

$$\left(\frac{2}{3}\right)^2 + \frac{2}{9} \div \frac{1}{3}$$

A correct solution to this problem involves both the order of operations and operations with fractions. Thus, this one problem covers two objectives. In my analysis, a student received two separate scores for this particular problem based on how he or she performed on each objective.

I listed the objectives for all 25 problems on the Basic Math Skills final exam. Many of the 25 problems had multiple parts, resulting in a total of 49 individual questions. A colleague also identified the objectives for each problem of the Basic Math Skills final exam. Using the objectives that I identified along with those of my colleague, I performed an interrater reliability analysis using SPSS to calculate the Kappa statistic. The interrater reliability for the raters was found to be Kappa = 0.918 ($p < 0.001$), 95% CI (0.870, 0.966). This is generally considered "almost perfect agreement" (Landis & Koch, 1977). With this established, I considered the differences among my colleague and I to obtain a final list of objectives.

Of the objectives listed, several had only one or two occurrences on the final exam. Thus, the decision was made to only include the objectives with four or more instances. This process identified eight major objectives that appeared on the exam: (1) *operations with integers*; (2) *operations with fractions*; (3) *operations with decimals*; (4) *order of operations*; (5) *combining like terms*; (6) *solving linear equations*; (7) *using the rules of exponents*; and (8) *applying the distributive property*. One objective, *operations with integers*, occurred 23 times while the other objectives occurred between four and seven times each. In order to minimize the difference between the frequencies of each objective, I decided to analyze only a subset of the problems which included *operations with integers*. I chose to include the problems which were already included due to one of the other seven objectives (this was 10 occurrences) and also two problems in which *operations with integers* was the only objective. As a result, 55% of the final exam was used in the final analysis. The resulting frequency for each objective included in the analysis is listed in *Table 3.10*.

Objective	**Frequency**
Operations with integers	12
Operations with fractions	7
Operations with decimals	6
Order of operations	4
Combining like terms	5
Solving linear equations	5
Using the rules of exponents	4
Applying the distributive property	4

Table 3.10. Objectives on the Basic Math Skills final exam.

The objectives above are consistent with mathematics curriculum objectives in educational standards across the nation. Since the content of Basic Math Skills includes objectives initially taught in elementary and middle school, many of the standards listed correspond to grades lower than high school. *Table 3.11* lists the objectives along with their locations in both the Common Core State Standards (Common Core State Standards Initiative, 2010) and the Texas Essential Knowledge and Skills, or *TEKS* (Texas Education Agency, 2012). These two particular sets of standards were chosen to provide both a broad set of standards with the Common Core State Standards as well as a set of standards specific to the state where this research takes place. The Common Core State Standards have been adopted in 45 states and three territories of the United States (Texas not being one of those).

Objective	**Common Core State Standards**	**Texas Essential Knowledge and Skills**
Operations with integers	**Grade 7:** "Apply properties of operations as strategies to add and subtract rational numbers." (p. 48)	**TEKS 7.2 (C):** "The student is expected to use models, such as [concrete objects,] pictorial models, and number lines, to add, subtract, multiply, and divide integers and connect the actions to algorithms."
	Grade 7: "Apply properties of operations as strategies to multiply and divide rational numbers." (p. 49)	
	Grade 7: "Solve real-world and mathematical problems involving the four operations with rational numbers." (p. 49)	
Operations with fractions	**Grade 5:** "Use equivalent fractions as a strategy to add and subtract fractions." (p. 34)	**TEKS 6.2 (B):** "The student is expected to use addition and subtraction to solve problems involving fractions and decimals."
	Grade 5: "Apply and extend previous understandings of multiplication and division to multiply and divide fractions." (p. 34)	**TEKS 7.2 (B):** "The student is expected to use addition, subtraction, multiplication, and division to solve problems involving fractions and decimals."
Operations with decimals	**Grade 5:** "Perform operations with multi-digit whole numbers and with decimals to hundredths." (p. 34)	**TEKS 7.2 (B):** "The student is expected to use addition, subtraction, multiplication, and division to solve problems involving fractions and decimals."
Order of operations	**Grade 3:** "… students should know how to perform operations in the conventional order when there are no parentheses to specify a particular order (Order of Operations)." (p. 23).	**TEKS 6.2 (E)**: "The student is expected to use order of operations to simplify whole number expressions (without exponents) in problem solving situations."
	Grade 6: "Perform arithmetic operations, including those involving whole number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations)." (p. 44)	**TEKS 7.2 (E):** "The student is expected to simplify numerical expressions involving order of operations and exponents."

Table 3.11. Basic Math Skills objectives in the standards.

Objective	Common Core State Standards	Texas Essential Knowledge and Skills
Combining like terms	**Grade 7:** "Apply properties of operations as strategies to add, subtract, factor, and expand linear expressions with rational coefficients." (p. 49)	**TEKS A.4 (B):** "The student is expected to use the commutative, associative, and distributive properties to simplify algebraic expressions."
Solving linear equations	**Grade 6:** "Reason about and solve one-variable equations and inequalities." (p. 41)	**TEKS A.7 (B):** "The student is expected to investigate methods for solving linear equations and inequalities using [concrete] models, graphs, and the properties of equality, select a method, and solve the equations and inequalities."
	Grade 8: "Analyze and solve linear equations and pairs of simultaneous linear equations." (p. 53)	
	Grade 8: "Solve linear equations with rational number coefficients, including equations whose solutions require expanding expressions using the distributive property and collecting like terms." (p. 54)	
Using the rules of exponents	**Grade 8:** "Know and apply the properties of integer exponents to generate equivalent numerical expressions. For example, 32 × 3–5 = 3–3 = 1/33 = 1/27." (p. 54)	**TEKS A.11 (A):** "The student is expected to use patterns to generate the laws of exponents and apply them in problem-solving situations."
Applying the distributive property	**Grade 6:** "Apply the properties of operations to generate equivalent expressions. For example, apply the distributive property to the expression 3 (2 + x) to produce the equivalent expression 6 + 3x." (p. 44)	**TEKS A.4 (B):** "The student is expected to use the commutative, associative, and distributive properties to simplify algebraic expressions."

Table 3.11, continued. Basic Math Skills objectives in the standards.

In addition to appearing in the Common Core State Standards and the *TEKS*, these objectives appear in research regarding student preparation for algebra. For example, Gallardo (2002) noted that from a historical perspective, students' experiences with and understanding of extending the natural numbers to integers is an essential element to the development of algebraic thinking and the ability to solve equations. A deep understanding of the number system and the operations that go with it are considered necessary to build algebraic fluency (Lee & Wheeler, 1989; Slavit, 1998). Demana and Leitzel (1988) also emphasized that skills such as the order of operations, operations with negative numbers, and the distributive property are essential to students' success in algebra courses.

Rubric Development

After identifying the most common objectives on the Basic Math Skills final exam, I scored the final exams according to a rubric that I developed with several colleagues. The rubric is provided in Appendix C and details how to score each final exam question that was included in the analysis. Each student received eight scores ranging from zero to one for the objectives listed above. Specific guidelines for intermediate scores (for example 0.4 or 0.7) are given in the rubric (Appendix C). The student's score for each objective is obtained by averaging the objective score from each question on which that objective appeared. For example, the objective *order of operations* appears on four separate questions from the final exam. A student would thus get an *order of operations* score on each of these questions, and the average (again ranging from zero to one) would be reported as the student's overall score for that objective.

In the initial stages of the rubric development, two of my colleagues and I scored four sample exams. Throughout this process, we discussed any discrepancies and addressed how to modify the rubric to avoid discrepancies in the future. Once the rubric had been modified, a third colleague scored 19 sample exams. I also scored these same 19 exams and performed an interrater reliability analysis using SPSS to calculate the Kappa statistic. The interrater reliability for the raters was found to be Kappa = 0.934 ($p < 0.001$), 95% CI (0.910, 0.958). This is generally considered "almost perfect agreement" (Landis & Koch, 1977, p. 165). I then scored the remaining exams myself and obtained an objective score for each student who had a final exam.

College Algebra

Objectives

Analysis of the College Algebra final exams presented an additional challenge. The final exams are written by the individual instructor, and while they cover the same topics, the problems are not identical. However, two sections of final exams for the lecture classes were the same and all the final exams (with the exception of one small class) for the student-led classes were the same (due to collaboration among the instructors). One student-led section and one lecture section had final exams that were different from the majority of the other final exams in the corresponding instruction method. I will discuss dealing with this issue in a later paragraph.

Comparing the final exams for the student-led and lecture sections, I found five pairs questions which had closely aligned objectives and methods of assessment. In total, there were 18 questions on the lecture final exams and 10 questions on the student-led final exams. These questions comprised approximately 28 and 50 percent of the problems given on the lecture and student-led finals, respectively. The main objectives on these five questions were: (1) *write the equation of a line in slope-intercept form given a point and the slope*; (2) *write the equation of an exponential function given two data points*; (3) *model a situation with a system of two linear equations and solve*; (4) *use properties of logarithms to write an expression as a single logarithm*; and (5) *solve an exponential equation*. *Table 3.12* shows the objectives and the corresponding problem numbers on the final exams.

While the objectives here are somewhat constrained by the available data (the final exams), they are also aligned with the Common Core State Standards and *TEKS*. *Table 3.13* lists the standards associated with the selected objectives.

Objective	SL	Lecture
Write the equation of a line in slope-intercept form given a point and slope	#1c	Part 1 #2
Write the equation of an exponential function given two data points	#4	Part 2 #8a
Model a situation with a system of two linear equations and solve	#6	Part 2 #5
Use properties of logarithms to write an expression as a single logarithm	#7	Part 2 #7
Solve an exponential equation	#8	Part 2 #6

Table 3.12. Selected objectives from the College Algebra final exams.

Objective	Common Core State Standards	Texas Essential Knowledge and Skills
Write the equation of a line in slope-intercept form given a point and the slope	**High School - Functions:** "Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table)." (p. 71)	**TEKS A.6 (D):** "The student is expected to graph and write equations of lines given characteristics such as two points, a point and a slope, or a slope and y-intercept."
Write the equation of an exponential function given two data points	**High School - Functions:** "Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table)." (p. 71)	**TEKS 2A.11 (F):** "The student is expected to analyze a situation modeled by an exponential function, formulate an equation or inequality, and solve the problem."
Model a situation with a system of two linear equations and solve	**High School - Algebra: "**Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables." (p. 66)	**TEKS 2A.3 (A):** "The student is expected to analyze situations and formulate systems of equations in two or more unknowns or inequalities in two unknowns to solve problems."
Use properties of logarithms to write an expression as a single logarithm	**High School - Functions:** "Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents." (p. 70)	**TEKS 2A.11 (A):** "The student is expected to develop the definition of logarithms by exploring and describing the relationship between exponential functions and their inverses."
Solve an exponential equation	**High School - Functions:** "Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents." (p. 70)	**TEKS 2A.11 (D):** "The student is expected to determine solutions of exponential and logarithmic equations using graphs, tables, and algebraic methods."

Table 3.13. Selected College Algebra objectives in the standards.

Rubric Development

The method used to develop the rubric for analysis of the College Algebra final exams was very similar to the method used for the Basic Math Skills final exams. The rubric is provided in Appendix C and gives detailed descriptions for scoring each question included in the analysis. Again, scores range from zero to one for each question. For the College Algebra exams, only one score was provided for each question rather than breaking each question down into several objectives. The reason for this method of analysis is that the questions themselves are aimed at particular College Algebra objectives, and smaller objectives such as the order of operations or combining like terms were not part of the College Algebra curriculum itself. Instead, students are expected to have acquired these types of skills in prerequisite classes.

Again, a colleague and I scored sample exams. This time we scored four from each type of class (lecture or student-led) since the finals were different. We discussed any discrepancies and adjusted the rubric as necessary to address these situations. A different colleague and I then scored 26 exams (13 from each type of class) and recorded the scores. I used SPSS to check for interrater reliability by calculating the Kappa statistic. The interrater reliability was found to be Kappa = 0.958 (p<.001), 95% CI (0.911, 1.000), which is again considered "almost perfect agreement" (Landis & Koch, 1977). Once interrater reliability was established, I scored the remaining College Algebra final exams myself and assigned each student a score for each objective.

Remaining Two Sections of Exams

As mentioned above, there were two remaining sections of exams that differed from the majority. These were part of the last round of data collection. Rather than omitting these final exams from my analysis, I found four questions from the student-led section and one question from the lecture section that lined up with the previous exams. I scored these exams and included them in the analysis. Students from these two sections simply have missing scores for the remaining objectives, and as a result the sample size in the final exam analysis varies from objective to objective. The sample size for the analysis of each objective will be noted when the results are presented.

Analysis

I used paired *t*-tests to compare students' results on the final exams across instruction types (student-led and lecture) and by course (College Algebra or Basic Math Skills). Additionally, I used the final exam scores to determine if there was a correlation between these results and the composite attitudinal variables. As outlined in Chapter Two, there is ample literature to warrant investigating this relationship (Aiken, 1970; Elliot & Dweck, 2005; Laursen et al., 2011; Liu, 2010; Mangels et al., 2006; Panaoura et al., 2009; Rethinam, 2004; Weber, 2008). The results of these analyses are given in Chapter Four.

SUMMARY

In summary, I used the combined analysis of the observations, final exam data, and attitudinal surveys to answer the following research questions:

1. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' attitudes about math?
2. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' mathematical content knowledge?
3. Are community college students' attitudes about mathematics connected to their mathematical content knowledge?

The first research question was addressed by comparing the pre- and post-attitudinal surveys from the student-led sections to the lecture sections. The second research question was addressed by comparing the final exams of students in student-led sections to lecture sections. I did this using the rubrics described above (included in Appendix C), which allowed student content knowledge on routine problems to be analyzed objective by objective. Finally, I addressed the third research question using the final exam data and attitudinal surveys. This allowed me to determine if specific attitudinal variables were correlated with student knowledge on individual objectives from the final exams.

LIMITATIONS OF THIS STUDY

Instruments

In both Basic Math Skills and College Algebra, the final exam questions tended to be very routine calculation-based problems. This lack of more conceptual questions limited the conceptual understanding that could be measured using these particular exams. Additionally, while Basic Math Skills final exams were the same across all sections, the analysis of College Algebra final exams was limited to 50% of the final for student-led sections and 28% of the final for lectures sections. While other questions covered similar content for both classes, they were typically asked in very different ways, which hindered any potential comparison. Future studies might consider creating and validating an evaluation instrument that is more open-ended and attempts to investigate further into students' understanding of algebraic concepts. Instructor willingness to allow the researchers use of class time was also a limiting factor. Specifically, in College Algebra, several instructors did not allow the researchers any use of class time, and surveys were administered online. Thus, content assessments were limited to the collection of final exams. Recruiting instructors willing to allow use of class time (or require alternate assessments outside of class) is not a trivial issue. Departmental support of a future research project could help with recruitment and class time issues.

Study size

Several factors contribute to the study size. First, as noted in the literature review, these particular mathematics courses at community colleges have low retention rates. Thus, many students who were present at the beginning of the study and consented to allowing use of their data were no longer enrolled/attending at the time of the post-survey and final exam. This attrition greatly reduced the number of students included in the data analysis. Future studies may be able to address this issue by having more instructors with multiple sections of the same course and instruction type.

Chapter Four: Results

SURVEY ANALYSIS

To address my first research question ("Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' attitudes about math?"), I analyzed the average changes in the attitudinal surveys (from the beginning of the semester to the end of the semester) using paired *t*-tests on each group (A: Basic Math Skills – Student-led, B: Basic Math Skills – Lecture, C: College Algebra – Student-led, and D: College Algebra – Lecture). The results are shown in *Table 4.1.* For each *t*-test, I have reported the associated *p*-value and effect size (Cohen's *d*), which is in terms of the effect that taking the class had on students' attitudes. That is, the effect is calculated from baseline scores on the pre-survey.

Performing 17 *t*-tests on the same participants leads to the question of whether or not a Bonferroni correction is necessary. Bonferroni corrections are used to reduce the Type I error rate of the overall study. That is, the correction (which consists of dividing typical accepted error rates by 17, the number of comparisons for each group) is only applicable to the universal null hypothesis which claims that all 17 variables are equal. It thus adjusts for the likelihood that the researcher will reject the universal null hypothesis when in fact it should not be rejected. However, because I am retaining or rejecting individual hypotheses which are measuring different constructs (as validated in the methodology section), the argument can be made that I do not need an adjustment, and such an adjustment would in fact inflate Type II error rates (failing to reject the null hypotheses and find a difference when there is in fact a difference among the two groups being compared) (Gelman, Hill, & Yajima, 2012; Perneger, 1998). However, I have also provided an interpretation of the results with adjusted error rates. These adjustments take

Average Changes in Attitudes from Pre-Survey to Post-Survey

Attitudinal Variable		Basic Math						College Algebra					
		Group A: Student-led			Group B: Lecture			Group C: Student-led			Group D: Lecture		
		Change	*p*-value	Effect Size (*d*)	Change	*p*-value	Effect Size (*d*)	Change	*p*-value	Effect Size (*d*)	Change	*p*-value	Effect Size (*d*)
		(N = 22)			(N = 25)			(N = 54)			(N = 43)		
Motivation	*Interest*	1.05	0.0004	0.91	0.22	0.554	0.12	0.15	0.495	0.09	0.63	0.003	0.49
	Math future	0.66	0.057	0.43	0.54	0.172	0.28	0.44	0.008	0.38	0.53	0.007	0.43
	Teaching	0.36	0.296	0.23	-0.33	0.435	-0.16	-0.02	0.925	-0.01	-0.12	0.657	-0.07
Enjoyment	*Enjoyment*	0.79	0.015	0.56	0.46	0.156	0.29	0.26	0.056	0.27	0.15	0.408	0.13
Confidence	*Math confidence*	0.13	0.669	0.09	-0.07	0.850	-0.04	-0.26	0.063	-0.26	-0.24	0.158	-0.22
	Teaching confidence	0.33	0.303	0.23	0.60	0.109	0.33	-0.16	0.369	-0.12	0.14	0.513	0.10
Goals	*Intrinsic*	0.20	0.403	0.18	0.02	0.935	0.02	-0.30	0.068	-0.25	0.08	0.631	0.07
	Extrinsic	0.05	0.789	0.06	-0.42	0.157	-0.29	-0.30	0.008	-0.37	-0.06	0.619	-0.08
	Communicating	-0.21	0.577	-0.12	-0.21	0.527	-0.13	-0.50	0.003	-0.42	0.34	0.065	0.29
Beliefs about learning	*Instructor-driven*	0.18	0.432	0.17	0.03	0.816	0.05	-0.08	0.568	-0.08	-0.08	0.535	-0.10
	Group work	0.89	0.038	0.47	0.07	0.822	0.05	0.07	0.757	0.04	0.19	0.192	0.20
	Exchange of ideas	0.12	0.713	0.08	0.56	0.168	0.28	-0.23	0.288	-0.15	0.53	0.009	0.41
Beliefs about problem-solving	*Practice*	0.27	0.361	0.20	0.20	0.589	0.11	0.13	0.408	0.11	0.08	0.635	0.07
	Reasoning	0.53	0.053	0.44	0.26	0.275	0.22	0.13	0.226	0.17	0.08	0.561	0.09
Strategies	*Independent*	0.15	0.517	0.14	0.47	0.143	0.30	0.12	0.446	0.10	-0.13	0.549	-0.09
	Collaborative	0.42	0.286	0.23	0.07	0.828	0.04	-0.17	0.401	-0.12	0.19	0.362	0.14
	Self-regulatory	0.11	0.613	0.11	0.07	0.773	0.06	-0.13	0.242	-0.16	-0.20	0.132	-0.23

P-values: $p < 0.001$; $p < 0.01$; $p < 0.05$; $p < 0.1$

Effect Sizes: small: $.2 \le |d| < .5$; medium: $.5 \le |d| < .8$; large: $|d| \ge .8$

Table 4.1. Changes in composite attitudinal variables.

Average Changes in Attitudes from Pre-Survey to Post-Survey

Attitudinal Variable		Basic Math						College Algebra					
		Group A: Student-led			Group B: Lecture			Group C: Student-led			Group D: Lecture		
		Change	*p*-value	Effect Size (*d*)	Change	*p*-value	Effect Size (*d*)	Change	*p*-value	Effect Size (*d*)	Change	*p*-value	Effect Size (*d*)
		(N = 22)			(N = 25)			(N = 54)			(N = 43)		
Motivation	*Interest*	1.05	0.0004	0.91	0.22	0.554	0.12	0.15	0.495	0.09	0.63	0.003	0.49
	Math future	0.66	0.057	0.43	0.54	0.172	0.28	0.44	0.008	0.38	0.53	0.007	0.43
	Teaching	0.36	0.296	0.23	-0.33	0.435	-0.16	-0.02	0.925	-0.01	-0.12	0.657	-0.07
Enjoyment	*Enjoyment*	0.79	0.015	0.56	0.46	0.156	0.29	0.26	0.056	0.27	0.15	0.408	0.13
Confidence	*Math confidence*	0.13	0.669	0.09	-0.07	0.850	-0.04	-0.26	0.063	-0.26	-0.24	0.158	-0.22
	Teaching confidence	0.33	0.303	0.23	0.60	0.109	0.33	-0.16	0.369	-0.12	0.14	0.513	0.10
Goals	*Intrinsic*	0.20	0.403	0.18	0.02	0.935	0.02	-0.30	0.068	-0.25	0.08	0.631	0.07
	Extrinsic	0.05	0.789	0.06	-0.42	0.157	-0.29	-0.30	0.008	-0.37	-0.06	0.619	-0.08
	Communicating	-0.21	0.577	-0.12	-0.21	0.527	-0.13	-0.50	0.003	-0.42	0.34	0.065	0.29
Beliefs about learning	*Instructor-driven*	0.18	0.432	0.17	0.03	0.816	0.05	-0.08	0.568	-0.08	-0.08	0.535	-0.10
	Group work	0.89	0.038	0.47	0.07	0.822	0.05	0.07	0.757	0.04	0.19	0.192	0.20
	Exchange of ideas	0.12	0.713	0.08	0.56	0.168	0.28	-0.23	0.288	-0.15	0.53	0.009	0.41
Beliefs about problem-solving	*Practice*	0.27	0.361	0.20	0.20	0.589	0.11	0.13	0.408	0.11	0.08	0.635	0.07
	Reasoning	0.53	0.053	0.44	0.26	0.275	0.22	0.13	0.226	0.17	0.08	0.561	0.09
Strategies	*Independent*	0.15	0.517	0.14	0.47	0.143	0.30	0.12	0.446	0.10	-0.13	0.549	-0.09
	Collaborative	0.42	0.286	0.23	0.07	0.828	0.04	-0.17	0.401	-0.12	0.19	0.362	0.14
	Self-regulatory	0.11	0.613	0.11	0.07	0.773	0.06	-0.13	0.242	-0.16	-0.20	0.132	-0.23

P-values: $p < 0.00006$; $p < 0.0006$; $p < 0.003$; $p < 0.006$

Effect Sizes: small: $.2 \le |d| < .5$; medium: $.5 \le |d| < .8$; large: $|d| \ge .8$

Table 4.2. Changes in composite attitudinal variables with Bonferroni adjustment.

the error rates highlighted in *Table 4.1* (0.001, 0.01, 0.05, and 0.1) and divide each one by 17 (the number of *t*-tests I ran for each group). The results are given in *Table 4.2*.

A few key differences in the attitudinal variables can be seen in *Table 4.1*. For Basic Math students in student-led classes, there were significant (or near significant) increases in the following areas:

- *interest in mathematics* ($p<0.001$)
- *math future* ($p<0.1$)
- *enjoyment* ($p<0.05$)
- *group work* ($p<0.05$)
- *reasoning* ($p<0.1$).

There were no significant changes for students enrolled in lecture sections of Basic Math. Students who were enrolled in student-led sections of College Algebra had significant (or near significant) increases in the following areas:

- *math future* (p<0.01)
- *enjoyment* ($p<0.1$).

They also had significant (or near significant) decreases in the following areas:

- *math confidence* ($p<0.1$)
- *intrinsic goals* ($p<0.1$)
- *extrinsic goals* ($p<0.01$)
- *communicating* ($p<0.01$).

Finally, students enrolled in lecture sections of College Algebra had significant (or near significant) increases in the following areas:

- *interest in mathematics* ($p<0.01$)
- *math future* ($p<0.01$)
- *communicating* ($p<0.\ 1$)

- *exchange of ideas* (p<0.01).

FINAL EXAM ANALYSIS

Using the rubrics described in Chapter Three, I scored each final exam for both Basic Math Skills and College Algebra. Using these scores, I was able to address my second research question, which was "Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' mathematical content knowledge?" The results for each course are below.

Basic Math Skills

The final exam rubric I developed for Basic Math Skills incorporated eight objectives, which can be seen below in *Table 4.3*. The mean scores (ranging from zero to one) for each class type can also be seen below for the eight objectives. I compared the means of each objective for student-led sections and lecture sections using independent t-tests. The resulting p-values and effect sizes (Cohen's d) are given in *Table 4.3*. Here, the effect sizes (had there been significant differences) would indicate the effect that taking a student-led class versus a lecture class had on students' objective scores. There were no significant differences between the two groups for any of the eight objectives.

College Algebra

The final exams collected from College Algebra courses were also scored using the rubric described in Chapter Three. Again, I compared the scores of the two class types using independent t-tests. The results are shown in *Table 4.4*. I found that the student-led sections performed better than the lecture sections on two objectives: *write the equation of a line in slope-intercept form* (p<0.001) and *use properties of logarithms to rewrite an equation* (p<0.01). Additionally, lecture sections performed better than the student-led sections on one objective: *write the equation of an exponential function* (p<0.05).

Basic Math Objective		**Mean**		***p*-value**	**Effect Size (Cohen's *d*)**
		Student-led	Lecture		
		(N = 26)	(N = 22)		
1	*Operations with integers*	0.83	0.77	0.263	0.28
2	*Operations with fractions*	0.66	0.67	0.966	- 0.01
3	*Operations with decimals*	0.74	0.71	0.669	0.11
4	*Order of operations*	0.82	0.78	0.519	0.16
5	*Combining like terms*	0.69	0.73	0.588	- 0.15
6	*Solving linear equations*	0.70	0.78	0.311	- 0.27
7	*Using the rules of exponents*	0.76	0.76	0.903	0.03
8	*Applying the distributive property*	0.78	0.76	0.801	- 0.06

Table 4.3. Basic Math Skills final exam results.

College Algebra Objective		**Student-led**		**Lecture**		***p*-value**	**Effect Size (Cohen's *d*)**
		N	Mean	N	Mean		
1	*Write the equation of a line in slope-intercept form*	67	0.98	33	0.84	0.0001	0.87
2	*Write the equation of an exponential function*	63	0.60	33	0.80	0.016	- 0.53
3	*Model and solve a situation with a system of two linear equations*	78	0.95	33	1.00	0.123	- 0.32
4	*Use properties of logarithms to rewrite an expression*	78	0.78	33	0.57	0.003	0.66
5	*Solve an exponential equation*	78	0.84	50	0.81	0.569	0.11

p-values: $p < 0.001$; $p < 0.01$; $p < 0.05$

Effect sizes: small: between .2 and .5 ; medium: between .5 and ; large: greater than .8

Table 4.4. College Algebra final exam results.

ATTITUDES AND CONTENT KNOWLEDGE

The final analysis I performed was to consider the correlation, if any, between the individual final exam objectives and specific composite attitudinal survey variables. This enabled me to address my third research question, "Are community college students' attitudes about mathematics connected to their mathematical content knowledge?" To complete this analysis, I used SPSS to calculate the Pearson coefficient for each pair of attitudinal variables and final exam objectives. The Pearson coefficient measures the strength of a potential linear relationship between two variables.

Basic Math Skills

When I examined the pre-surveys for Basic Math Skills, I only found two statistically significant correlations amongst the 17 attitudinal variables and eight objectives. The significant correlations are highlighted in *Table 4.5*, and in both instances the correlation was negative. However, the results from analyzing the post-survey results indicated many more pairs that were correlated. To be exact, 21 pairs of attitudinal variables and objectives were positively correlated and one pair was negatively correlated. The results from all 136 regression analyses for the post-survey data are summarized in *Table 4.6*.

College Algebra

I performed a similar analysis for the College Algebra surveys and final exams, this time comparing all 17 composite attitudinal variables to the five College Algebra objectives. The analysis using the pre-surveys found 14 significantly correlated pairs, all of which were positively correlated. A notable finding was that objective five, *solve an exponential equation,* was positively correlated with eight out of 17 of the composite attitudinal variables. The results from the pre-survey analysis can be seen in *Table 4.7*. The analysis using the post-surveys did not result in as many significant findings. There were only six significantly correlated pairs, all of which were positively correlated. Complete findings for the post-surveys and College Algebra objectives are reported in *Table 4.8*.

Attitudinal Variable			Basic Math Objective															
			1		2		3		4		5		6		7		8	
			(n = 48)		(n = 48)		(n = 48)		(n = 48)		(n = 48)		(n = 48)		(n = 48)		(n = 48)	
			r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
	Motivation	*Interest*	.046	.758	.177	.230	-.028	.852	.057	.698	.129	.383	.203	.167	.109	.462	.198	.178
		Math future	.034	.820	.006	.968	-.044	.767	-.016	.914	-.091	.540	-.066	.657	.155	.293	.069	.640
		Teaching	-.199	.180	-.055	.714	-.139	.351	-.059	.693	-.121	.418	-.096	.519	.029	.847	-.106	.477
	Enjoyment	*Enjoyment*	-.001	.997	.140	.344	-.011	.941	-.046	.755	.128	.385	.188	.201	.146	.322	.137	.354
	Confidence	*Math confidence*	.011	.939	.114	.445	.152	.308	-.010	.946	.158	.290	.144	.335	.053	.726	.010	.948
		Teaching confidence	-.084	.576	.011	.940	-.092	.538	-.206	.165	.097	.515	.108	.469	-.148	.319	-.048	.751
	Goals	*Intrinsic*	-.110	.457	-.006	.969	.000	.999	-.119	.422	-.045	.759	-.067	.651	.019	.896	-.027	.853
		Extrinsic	-.109	.461	.114	.441	.020	.892	.060	.684	-.007	.965	-.072	.626	.223	.127	-.021	.888
		Communicating	-.153	.298	-.024	.872	-.066	.655	-.008	.959	-.109	.460	-.157	.285	.117	.430	-.083	.575
	Beliefs about learning	*Instructor-driven*	-.057	.701	.023	.876	.059	.692	.071	.633	-.080	.590	-.216	.141	.048	.748	.016	.912
		Group work	-.072	.627	-.065	.660	.057	.700	-.133	.367	-.063	.673	-.120	.417	.186	.206	-.039	.792
		Exchange of ideas	-.069	.641	.034	.820	.088	.552	-.147	.319	.115	.437	-.009	.953	.040	.786	-.048	.746
	Beliefs about problem-solving	*Practice*	.030	.842	-.151	.310	.008	.956	.031	.837	-.185	.213	-.201	.176	.100	.503	-.101	.498
		Reasoning	-.184	.215	-.193	.194	-.065	.663	-.172	.247	-.364*	.012	-.367*	.011	-.088	.556	-.196	.186
	Strategies	*Independent*	-.144	.328	.011	.940	.085	.566	-.084	.571	-.165	.262	-.190	.197	.020	.893	-.118	.426
		Collaborative	-.062	.676	-.051	.728	-.061	.680	-.055	.710	-.009	.949	-.021	.887	-.008	.959	-.191	.192
		Self-regulatory	-.030	.841	.104	.480	.127	.390	.004	.977	-.059	.690	-.079	.596	-.072	.627	-.090	.544

P-values: $p < 0.01$ $p < 0.05$

Table 4.5. Basic Math Skills pre-survey attitude and content knowledge correlation results.

Attitudinal Variable		1 (n = 46) r	1 p	2 (n = 46) r	2 p	3 (n = 46) r	3 p	4 (n = 46) r	4 p	5 (n = 46) r	5 p	6 (n = 46) r	6 p	7 (n = 46) r	7 p	8 (n = 46) r	8 p
Motivation	*Interest*	.200	.182	.355*	.015	.139	.356	.121	.424	.158	.295	.226	.131	.118	.434	.131	.385
	Math future	.182	.227	.389**	.008	.307*	.038	.082	.586	.183	.223	.167	.266	-.002	.990	.179	.235
	Teaching	.107	.480	.210	.162	.085	.573	.158	.295	.168	.265	.133	.380	.053	.725	.116	.442
Enjoyment	*Enjoyment*	.100	.510	.351*	.017	.265	.075	-.045	.766	.147	.330	.141	.350	.103	.494	.059	.059
Confidence	*Math confidence*	.336*	.022	.434**	.003	.435**	.003	.179	.234	.305*	.039	.317*	.032	.059	.699	.220	.141
	Teaching confidence	.229	.126	.351*	.017	.249	.095	.082	.586	.387**	.008	.426**	.003	.000	1.000	.228	.127
Goals	*Intrinsic*	.070	.643	.130	.390	.094	.534	-.144	.339	-.014	.926	-.056	.710	.163	.280	.014	.925
	Extrinsic	.111	.463	.140	.353	.022	.884	-.012	.939	.152	.312	.082	.588	.314*	.033	.132	.382
	Communicating	.023	.880	.153	.310	-.015	.920	-.137	.363	.013	.933	-.026	.866	.232	.120	.005	.972
Beliefs about learning	*Instructor-driven*	.166	.271	.260	.081	.303*	.041	.161	.285	.104	.490	-.005	.975	.309*	.037	.049	.745
	Group work	.073	.631	.096	.525	.189	.209	-.017	.911	-.020	.894	-.129	.392	.164	.277	.094	.536
	Exchange of ideas	.296*	.046	.387**	.008	.460**	.001	.079	.603	.196	.193	.206	.170	.183	.223	.190	.206
Beliefs about problem-solving	*Practice*	.173	.250	.304*	.040	.220	.142	.155	.302	.162	.282	.031	.840	.204	.173	.206	.170
	Reasoning	-.113	.455	-.038	.802	.171	.257	-.240	.108	-.251	.093	-.272	.068	-.043	.778	-.207	.168
Strategies	*Independent*	-.177	.238	-.096	.527	.000	.999	-.239	.110	-.269	.070	-.225	.132	-.063	.679	-.311*	.036
	Collaborative	.005	.973	-.080	.598	-.020	.895	-.136	.369	-.030	.842	-.069	.651	-.056	.710	.000	.998
	Self-regulatory	.105	.488	.263	.077	.285	.055	.141	.349	.122	.421	.059	.696	.299*	.044	-.007	.961

P-values: $p < 0.01$ $p < 0.05$

Table 4.6. Basic Math Skills post-survey attitude and content knowledge correlation results.

Attitudinal Variable		College Algebra Objectives									
		1		2		3		4		5	
		(n = 81)		(n = 77)		(n = 89)		(n = 89)		(n = 106)	
		r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Motivation	*Interest*	.144	.198	.155	.177	-.126	.240	.217*	.041	.268**	.006
	Math future	.200	.073	-.041	.721	-.098	.362	.174	.103	.083	.398
	Teaching	-.010	.928	.153	.184	.024	.826	.161	.135	.210*	.032
Enjoyment	*Enjoyment*	.074	.509	.174	.130	-.057	.595	.131	.220	.194*	.047
Confidence	*Math confidence*	.080	.478	.180	.117	.089	.409	.243*	.022	.239*	.014
	Teaching confidence	.129	.251	.137	.236	.192	.071	.136	.203	.222*	.022
Goals	*Intrinsic*	.200	.074	.232*	.042	-.021	.847	.185	.082	.231*	.017
	Extrinsic	-.134	.234	.116	.316	-.132	.216	.012	.909	.210*	.030
	Communicating	.180	.107	.159	.168	.056	.605	.068	.525	.231*	.017
Beliefs about learning	*Instructor-driven*	.048	.669	.079	.497	-.065	.545	.080	.457	.046	.637
	Group work	.057	.613	-.086	.459	.065	.544	-.192	.072	-.018	.854
	Exchange of ideas	.286**	.010	-.074	.521	-.060	.576	.119	.267	-.010	.921
Beliefs about problem-solving	*Practice*	.052	.647	.129	.262	-.019	.857	.126	.239	.030	.762
	Reasoning	.188	.092	.130	.258	-.010	.924	.190	.074	.008	.936
Strategies	*Independent*	.168	.133	.299**	.008	-.072	.502	.157	.141	.080	.415
	Collaborative	.111	.322	-.056	.627	-.070	.516	.163	.127	.100	.306
	Self-regulatory	.123	.274	.276*	.015	-.054	.616	.049	.649	.171	.080

P-values: $p < 0.01$ $p < 0.05$

Table 4.7. College Algebra pre-survey attitude and content knowledge correlation results.

Attitudinal Variable		College Algebra Objectives									
		1		2		3		4		5	
		(n = 86)		(n = 79)		(n = 94)		(n = 94)		(n = 108)	
		r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Motivation	*Interest*	.184	.090	.177	.118	.080	.445	.089	.392	.207*	.032
	Math future	.145	.183	-.002	.986	.120	.251	.131	.209	.094	.333
	Teaching	.075	.493	.120	.294	.031	.764	.127	.223	.017	.865
Enjoyment	*Enjoyment*	.116	.288	.123	.280	.154	.138	.117	.263	.120	.215
Confidence	*Math confidence*	.164	.132	.120	.294	.141	.176	.218*	.035	.192*	.046
	Teaching confidence	.042	.701	.016	.887	.282**	.006	.153	.141	.174	.072
Goals	*Intrinsic*	.156	.153	.164	.148	.178	.087	.106	.309	.068	.486
	Extrinsic	-.026	.815	.071	.531	.083	.424	-.099	.342	.072	.457
	Communicating	.090	.410	.107	.349	.156	.133	-.065	.534	.110	.257
Beliefs about learning	*Instructor-driven*	.003	.979	.061	.592	-.035	.741	-.159	.125	.071	.465
	Group work	.051	.640	-.041	.718	.180	.083	-.109	.297	-.033	.731
	Exchange of ideas	.056	.608	.061	.592	.168	.106	.065	.534	-.102	.294
Beliefs about problem-solving	*Practice*	.171	.115	.007	.948	.035	.741	.165	.112	-.022	.820
	Reasoning	.220*	.042	.115	.314	.046	.657	.118	.259	-.022	.818
Strategies	*Independent*	.330**	.002	.094	.409	.118	.256	.108	.298	.038	.695
	Collaborative	.073	.506	-.092	.422	.127	.224	.072	.493	.070	.474
	Self-regulatory	.159	.144	.196	.084	.090	.390	.027	.797	.070	.474

P-values: $p < 0.01$ $p < 0.05$

Table 4.8. College Algebra post-survey attitude and content knowledge correlation results.

Chapter Five: Conclusions and Implications

RESEARCH QUESTIONS AND CONCLUSIONS

To review, the research questions investigated during this research were:

1. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' attitudes about math?
2. Does the incorporation of student-led teaching methods in two particular community college mathematics classes have an effect on those students' mathematical content knowledge?
3. Are community college students' attitudes about mathematics connected to their mathematical content knowledge?

Conclusions for Question One

Basic Math Skills

The survey analysis for Basic Math Skills included 47 matched pre- and post-surveys. Of these 47 surveys, 22 were from students in student-led sections and 25 were from students in lecture sections. Even with the small sample size, a few significant changes from the beginning of the semester to the end of the semester were observed in students' motivation, enjoyment, and beliefs. In *Table 4.1*, the impact on students' attitudes of taking Basic Math Skills is reported in the form of effect size (Cohen's d).

<u>Student-led courses had larger positive effects on students' motivation than lecture courses</u>

Participants in student-led sections expressed an increase of their interest in mathematics. This increase was statistically significant ($p = 0.0004$) and had a large effect size ($d > 0.8$). Additionally, student-led sections reported an increase in the likelihood of taking additional math courses or studying hard for mathematics ($p = 0.057$, $d = 0.43$).

Participants in lecture sections, on the other hand, showed much smaller increases in interest and math future. Neither increase was statistically significant. Finally, while student-led sections reported a slightly higher interest in teaching mathematics, lectures sections reported a slightly lower interest. Neither of these changes were significant, however.

An increased interest in mathematics and taking future math classes indicates that students in student-led classes may be having a more enjoyable experience learning mathematics. Unlike their peers enrolled in lecture sections, they were given more time during class to engage with the mathematics being taught. It could be possible that student-led sections allowed for more positive experiences during class, which furthered students' interest in studying mathematics.

<u>Student-led courses had a more positive effect on students' enjoyment of mathematics than lecture courses</u>

Participants in student-led sections of Basic Math Skills reported a significant increase in enjoyment of mathematics ($p = 0.015$, $d = 0.56$). Students in lecture sections also reported a slight increase in this area, but it was not significant. These results parallel the increases in motivation seen above. Again, it is conceivable that the environment created by instructors of student-led sections caused students to enjoy mathematics more than when they started the course.

<u>Student-led sections reported an increase in the importance of group work and reasoning, lectures sections did not</u>

Participants in student-led sections of Basic Math Skills showed a significant increase in their beliefs about the importance of group work in learning mathematics. This increase was statistically significant ($p = 0.038$) and had a small effect size ($d = 0.47$). The same increase was not present in lecture sections. Student-led sections also reported an increase in using reasoning to solve mathematical problems ($p = 0.053$, $d = 0.44$). Lecture sections showed a much smaller increase, which was not statistically significant.

It is not surprising that students who spent more time in class working in groups (those in student-led sections) had a change in how they viewed group work. The fact that students in these sections had an *increase* in their beliefs about the importance of this activity is noteworthy and indicates that students had positive experiences with group work during the semester. Finally, the increase in reasoning as a strategy for solving mathematical problems that student-led sections reported should not be overlooked. Reasoning is a skill highly valued in the workplace and often viewed by instructors as more important than algebraic content itself. Since instructors in student-led sections incorporated more problem-solving activities during class, it is reasonable to conclude that experiencing these activities caused students to change their beliefs about how reasoning helps them to solve problems.

<u>Other attitudinal changes for Basic Math Skills were not significant</u>

The above results report all changes which were either statistically significant in the traditional sense ($p < 0.05$) or close to this cutoff ($p < 0.1$). I chose to report those results which were near significant because the small sample size limited the statistical analyses, and these results give an indication of where we might find significant ($p < 0.05$) differences in a larger study. Other (non-significant) changes seen for participants in student-led sections were all positive with the exception of communication as a goal. For this particular variable, students in lecture sections also had a decrease of the same amount. In most other areas, the changes seen in lecture classes were either negative (when student-led changes were positive) or smaller increases than student-led sections. However, students in lecture sections did report a larger increase in their confidence in teaching mathematics. They also reported a larger increase in their beliefs about exchanging ideas and the use of independent learning strategies. However, none of these increases were significant.

College Algebra

The survey analysis for College Algebra included 97 matched pre- and post-surveys. Of these 97 surveys, 54 were from students in student-led sections and 43 were from students in lecture sections. A few significant changes were observed in both student-led and lecture sections. Again reported in *Table 4.1*, the impact of taking College Algebra is reported in the form of effect size (Cohen's *d*).

<u>Student-led sections and lecture sections had similar changes in motivation</u>

Participants in lecture sections of College Algebra reported significant ($p = 0.003$) increases in their interest in mathematics with a small effect size ($d = 0.49$). Participants in student-led sections showed a small increase in this area, but it was not statistically significant. Both groups of students reported increases in the likelihood of studying hard for math classes and taking future math classes. In both cases, the increase was statistically significant and showed a small effect size (student-led: $p = 0.008$, $d = 0.38$; lecture: $p = 0.007$, $d = 0.43$). Both groups of students reported a slightly lower interest in teaching mathematics on the post-survey, however neither of these decreases were significant.

<u>Student-led sections showed a larger increase in enjoyment than lecture sections</u>

Student-led sections of College Algebra reported a slightly larger increase in enjoyment of mathematics ($p = 0.056$, $d = 0.27$) than their peers who were in lecture sections. Again, it is reasonable to expect that students who engage more with the mathematics content during class might have a more enjoyable experience and therefore have an increased perception of enjoying mathematics.

<u>Both student-led and lecture sections reported a decrease in math confidence</u>

Participants in student-led sections reported a decrease ($p = 0.063$, $d = -0.26$) in math confidence. Lecture students reported a similar decrease, but the p value was higher and thus it was not statistically significant. These results indicate that it is possible that both groups lost confidence in their ability to do mathematics as a result of taking their first college-level mathematics course. It is possible that students were expecting an experience more similar to other lower-level classes they had taken in the past (either developmental courses at the community college or high school courses), and therefore the reported loss of confidence is common to both instruction methods.

Another explanation for this result is that through the acquisition of new knowledge and skills, students actually had a more realistic view of their mathematical abilities at the end of the course than at the beginning of the course. This phenomenon has been documented by Kruger and Dunning (1999), whose research showed that people tend to overestimate their abilities in domains where they lack knowledge. Furthermore, when the participants' skills were improved, their metacognitive competence helped them to realize their limitations and have a more accurate (albeit less favorable) estimation of their own skills.

<u>Student-led and lecture sections had opposite effects on students' goals</u>

After their College Algebra course, participants in student-led sections reported decreased importance of all three types of goals: intrinsic ($p = 0.068$, $d = -0.25$), extrinsic ($p = 0.008$, $d = -0.37$), and communicating ($p = 0.003$, $d = -0.42$). However, participants in lecture sections reported stronger communication goals ($p = 0.065$, $d = 0.29$) while showing almost no change in intrinsic or extrinsic goals.

It is difficult to say why student-led teaching strategies would lead students to have weaker intrinsic and communication goals. It is possible that students perceived themselves as meeting some of these goals throughout the semester, and therefore the goals became less important by the end of the semester. It is also possible that the teaching methods in student-led sections negatively affected students in these two areas. On the other hand, it is reasonable to conclude that student-led teaching methods would affect students' views of the importance of extrinsic goals like getting good grades and meeting degree requirements since student-led instructors may emphasize these things less than a more direct instructor. It is also difficult to say why students in lecture sections would have stronger communication goals at the end of their course while showing essentially no change in either of the other two types of goals. Perhaps their experience of listening to a lecture each day made them aware of the importance of clear communication in a mathematics classroom.

<u>Lecture sections indicated a positive change in their beliefs about the exchange of ideas</u>

After their College Algebra course, students in lecture sections reported stronger beliefs about learning through the exchange of ideas with others ($p = 0.009$, $d = 0.41$). This is another confusing result. It is unclear why lecture classes would have an effect on these beliefs when students in lecture sections of College Algebra essentially never interacted with each other during class.

<u>Other attitudinal changes for College Algebra were not significant</u>

As shown in *Table 4.1*, all other changes in College Algebra students' attitudes were small and not significant. Unlike in Basic Math Skills, there was not a clear pattern in the direction of these small changes. In both instruction methods, some changes were positive and some were negative.

Overall Conclusions for Question One

Overall, the above results of the survey analysis indicate that students enrolled in a developmental mathematics course may be more positively affected by IBL teaching strategies than those enrolled in College Algebra, which is a higher level course than Basic Math Skills. This finding is consistent with previous studies. Laursen et al. (2011) found that IBL classes tended to have a greater impact on lower achieving students while traditional lecture classes were more likely to benefit higher achieving students. Another study among middle and high school physics students also showed that IBL teaching strategies were "particularly beneficial for low-achieving students" (White & Frederiksen, 1998).

Conclusions for Question Two

Basic Math Skills

The final exam analysis for Basic Math Skills showed that participants in student-led sections performed similarly to students in lecture sections. Due to the routine nature of the problems on the Basic Math Skills final exam, this lack of effect is not surprising. Prior research indicates that in a semester-long course, students who experience inquiry-based learning classrooms may not perform better on routine tasks even if they have a greater conceptual understanding of the content (Kwon et al., 2005; Rasmussen et al., 2006).

Since the final exams in all Basic Math Skills sections were the same, this evidence presents a convincing argument that no harm is being done to students who experience a more student-centered classroom. That is, the lack of direct instruction in student-led sections did not decrease the amount of content knowledge that students gained from the course.

College Algebra

The analysis of the College Algebra final exams showed mixed results. Students in student-led sections performed significantly better than students in lecture sections on two of the five objectives: *write the equation of a line in slope-intercept form* (p = 0.0001, d = 0.87) and *use properties of logarithms to rewrite an expression* (p = 0.0026, d = 0.66). However, lecture sections performed better on one objective: *write the equation of an exponential function* (p = 0.0163, d = 0.53). This last result could potentially be due to the wording of the questions on the lecture exams. Unfortunately, the instructors in the lecture sections gave students the generic form of an exponential function, whereas none of the instructors in the student-led sections did so. Excerpts of the final exams showing these two questions can be seen in *Figure 5.1* and *Figure 5.2*.

4. (10 points) Find the equation for an exponential function, $f(x)$, that satisfies $f(0) = 4$ and $f(1) = 12$.

Figure 5.1. College Algebra student-led final exam problem.

8. (8 pts) There are initially 4000 bacteria per milliliter in a sample, and after 1 hour their concentration increases to 6000 bacteria per milliliter. Assume they grow exponentially.

A. Find C and a so that $f(x) = Ca^x$ fits the bacteria's growth.
B. How many bacteria are there after 2.5 hours?
C. After how long are there 8500 bacteria per milliliter?

Figure 5.2. College Algebra lecture final exam problem.

The fact that the final exams differ from section to section in College Algebra makes it difficult to conclude whether or not student-led teaching methods had an effect on content knowledge. However, on these particular objectives it seems that student-led sections did better than lecture sections overall. Thus, the data analysis suggests that student-led teaching strategies may increase student content knowledge of some objectives.

Conclusions for Question Three

My investigation of students' attitudinal variables and content knowledge showed a small number of significant correlations. For basic math students, almost no attitudinal variables from the pre-survey were correlated with objectives on the final exam (1.4% of the potential correlations). Only about 15.4% of the potential correlations were found to be significant for students' attitudinal variables from the post-survey. College Algebra students had somewhat opposite results. Using the pre-survey attitudinal variables, I found that about 16.5% of the potential correlations were significant. However, using post-survey attitudinal variables, only 7.1% of the pairs were significantly correlated. I have concluded that the relationship between students' attitudes and content knowledge cannot be clearly established with this data set, but there is evidence to warrant further investigation.

LIMITATIONS OF THIS RESEARCH

As previously mentioned in Chapter Three, both the instruments and study size were limiting factors. Many instructors simply did not have the class time to allow for the collection of assessments other than final exams. Therefore, assessments that allow for a more robust analysis of students' conceptual understanding were not developed or administered. Final exams were convenient to collect, but were already in existence and could not be changed. Specifically in College Algebra, this limited the analysis to common exam problems. Additionally, the retention rates in both Basic Math Skills and College Algebra impacted the number of students who had both pre-survey results and either post-survey or final exam results. Suggestions for further research given these limitations are outlined below.

IMPLICATIONS FOR FUTURE RESEARCH

While results from this study did not definitively establish all of the relationships investigated, there is ample evidence to warrant further investigation. Specifically, future studies should develop assessments that are more conceptually-oriented and open-ended rather than the routine calculation-type problems that were seen on both final exams in the current study. However, administering these assessments would most likely require support from a community college's administration. Future researchers should consider enlisting one or more community colleges interested in evaluating teaching methods to design a large-scale study. For example, common final exams or other required assessments may need to be modified to incorporate different types of questions, and this cannot be done without the support of mathematics departments.

Sample size may also be improved with administrative support. Future researchers should consider enlisting instructors who teach more than one section of the same course. This only happened a few times in the current study since many instructors only have one section of each course they are teaching. Having such instructors available and willing to participate may require the support of mathematics departments.

The research community also needs to investigate the idea that inquiry-based learning activities could prepare community college mathematics students students to learn more from lectures and texts. Schwartz and Bransford (1998) provided evidence that this strategy worked well for college psychology students. Their results indicated that lectures and expository materials can be valuable tools for learning when students have first had an opportunity to develop well-differentiated knowledge about a domain. The authors refer to this as a "time for telling" (Schwartz & Bransford, 1998). A mixture of inquiry-based learning activities and lecture may well be part of the solution to problems present in community college mathematics courses.

It is clear that large-scale studies are needed to determine what efforts can improve student outcomes in developmental mathematics courses at community colleges. We need to investigate methods that serve this population in a meaningful way. The incorporation of IBL teaching strategies is a mere starting point for improving student experiences nation-wide.

Appendix A: Instruments

Attitudinal Survey

Your interest in mathematics

***1. HOW LIKELY is it that you will...**

	Not at all likely						Extremely likely
Take additional math classes after College Algebra?	○	○	○	○	○	○	○
Study more than 10 hours a week for a college math course?	○	○	○	○	○	○	○
Read magazine or newspaper articles containing math related ideas?	○	○	○	○	○	○	○
Bring up mathematical ideas in a conversation outside of class?	○	○	○	○	○	○	○
Use ideas in this class to solve problems in real life?	○	○	○	○	○	○	○
Help a child with his or her homework?	○	○	○	○	○	○	○

Your enjoyment of mathematics

***2. HOW MUCH do you ENJOY...**

	No enjoyment						Extreme enjoyment
Working on a challenging mathematical problem?	○	○	○	○	○	○	○
Discovering a mathematical idea?	○	○	○	○	○	○	○
Seeing mathematics in everyday life?	○	○	○	○	○	○	○
Perceiving beauty in mathematical ideas?	○	○	○	○	○	○	○
Using rigorous reasoning to solve problems?	○	○	○	○	○	○	○
Thinking about abstract concepts?	○	○	○	○	○	○	○
Explaining mathematical ideas to other people?	○	○	○	○	○	○	○
Learning mathematical concepts?	○	○	○	○	○	○	○

Your goals in studying mathematics

***3. Below are some goals that students may have in studying mathematics. HOW IMPORTANT is each goal for YOU?**

	Not at all imporant						Extremely important
Learning specific procedures for solving math problems.	○	○	○	○	○	○	○
Improving your ability to communicate clearly to others.	○	○	○	○	○	○	○
Getting a good grade in college mathematics courses.	○	○	○	○	○	○	○
Memorizing the sets of facts important for doing mathematics.	○	○	○	○	○	○	○
Making mathematics understandable for other people.	○	○	○	○	○	○	○
Improving your ability to communicate mathematical ideas clearly to others.	○	○	○	○	○	○	○
Meeting the requirements for your degree.	○	○	○	○	○	○	○
Learning to construct convincing logical arguments.	○	○	○	○	○	○	○
Using mathematics as a tool to study other fields.	○	○	○	○	○	○	○
Learning new ways of thinking.	○	○	○	○	○	○	○
Applying mathematical thinking outside the college context.	○	○	○	○	○	○	○
Applying mathematical ideas in this class to real life situations.	○	○	○	○	○	○	○
Being able to solve difficult problems in real life.	○	○	○	○	○	○	○

Other goals (please specify below)

Your strategies for learning mathematics

***4. When you DO MATH, how often do you take each action listed below?**

	Very Seldom						Very Often
Study on your own.	○	○	○	○	○	○	○
Brainstorm with other students.	○	○	○	○	○	○	○
Try to organize or summarize your own ideas.	○	○	○	○	○	○	○
Discuss problem-solving strategies with other students.	○	○	○	○	○	○	○
Find your own ways of thinking and understanding.	○	○	○	○	○	○	○
Review your work for mistakes or misconceptions.	○	○	○	○	○	○	○
Complete homework assignments on time.	○	○	○	○	○	○	○
Plan a solving strategy before attacking a problem.	○	○	○	○	○	○	○
Try to find your own way to solve a problem.	○	○	○	○	○	○	○
Check your understanding of what the problem is asking.	○	○	○	○	○	○	○
Use your intuition about what the answer should be.	○	○	○	○	○	○	○
Look for an alternative strategy to solve a problem.	○	○	○	○	○	○	○
Give up when you get stuck.	○	○	○	○	○	○	○
Ask another student for help.	○	○	○	○	○	○	○
Ask the instructor or tutor for help.	○	○	○	○	○	○	○

Your preferences for learning mathematics

***5. Indicate how much you agree or disagree: I learn mathematics BEST when...**

	Strongly disagree						Strongly agree
The instructor lectures.	○	○	○	○	○	○	○
The class critiques other students' solutions.	○	○	○	○	○	○	○
I work on problems in a small group.	○	○	○	○	○	○	○
The exams challenge my mathematical skills.	○	○	○	○	○	○	○
Students present their solutions in class.	○	○	○	○	○	○	○
The instructor explains the solutions to problems.	○	○	○	○	○	○	○
I do homework which is similar to problems worked in class.	○	○	○	○	○	○	○
I do homework which is different from problems worked in class.	○	○	○	○	○	○	○
I study my class notes.	○	○	○	○	○	○	○
I can compare my math knowledge with other students.	○	○	○	○	○	○	○
I explain ideas to other students.	○	○	○	○	○	○	○
I get frequent feedback on my mathematical thinking.	○	○	○	○	○	○	○

Your strategies for solving problems

***6. Indicate how much you agree or disagree: In order to solve a challenging math problem, I NEED...**

	Not at all						Very much
To carefully analyze different possible solutions.	○	○	○	○	○	○	○
To have lots of practice in solving similar problems.	○	○	○	○	○	○	○
To understand other students' mathematical thinking when working in groups.	○	○	○	○	○	○	○
To have natural talent for mathematics.	○	○	○	○	○	○	○
To try multiple approaches to constructing a solution.	○	○	○	○	○	○	○
To remember a lot of examples that I might use in constructing a solution.	○	○	○	○	○	○	○
To use rigorous reasoning.	○	○	○	○	○	○	○
To have freedom to do the problem in my own way.	○	○	○	○	○	○	○
To work hard.	○	○	○	○	○	○	○

Your confidence in doing math

***7. HOW CONFIDENT are you that you can...**

	Not at all confident						Extremely confident
Get a high grade in this course?	○	○	○	○	○	○	○
Successfully work with complex mathematical ideas?	○	○	○	○	○	○	○
Explain mathematics to other students?	○	○	○	○	○	○	○
Develop new mathematical ideas?	○	○	○	○	○	○	○
Apply a variety of perspectives in solving problems?	○	○	○	○	○	○	○
Develop new ways to solve problems in your own life?	○	○	○	○	○	○	○
Present your work at the board in a math class?	○	○	○	○	○	○	○
Work on math problems with other students?	○	○	○	○	○	○	○
Teach math to children?	○	○	○	○	○	○	○

Background information

The purpose of this page is to match your pre-survey information with your post-survey information. None of your personal information will be shared with your instructor.

***8. What is your first name?**

***9. What is your last name?**

***10. What is your email address? (This information is secure and will not be used for any purpose other than contacting you regarding this specific study.)**

***11. What is your ethnicity?**

- Hispanic or Latino
- Not Hispanic or Latino

***12. Are you White, Black or African-American, American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific islander, or some other race?**

- White
- Black or African-American
- American Indian or Alaskan Native
- Asian
- Native Hawaiian or other Pacific Islander
- From multiple races

Some other race (please specify)

***13. What was your HIGH school GPA?**

- ◯ 4.1 or above
- ◯ 3.6 - 4.0
- ◯ 3.1 - 3.5
- ◯ 2.6 - 3.0
- ◯ 2.1 - 2.5
- ◯ 2.0 or below
- ◯ I don't know.

***14. What was the highest level of math that you took in HIGH SCHOOL?**

- ◯ Algebra, one year
- ◯ Algebra, two years
- ◯ Geometry with an algebra prerequisite
- ◯ Math models
- ◯ Other

***15. What is the highest level of school your MOTHER has completed or the highest degree she has received?**

- ◯ Less than high school degree
- ◯ High school degree or equivalent (e.g., GED)
- ◯ Some college but no degree
- ◯ Associate degree
- ◯ Bachelor degree
- ◯ Graduate degree
- ◯ I don't know

***16. What is the highest level of school your FATHER has completed or the highest degree he has received?**

- ◯ Less than high school degree
- ◯ High school degree or equivalent (e.g., GED)
- ◯ Some college but no degree
- ◯ Associate degree
- ◯ Bachelor degree
- ◯ Graduate degree
- ◯ I don't know

***17. How many semesters have you been enrolled in college?**

- ◯ This is my first semester.
- ◯ This is my second semester.
- ◯ This is my third semester.
- ◯ This is my fourth semester.
- ◯ This is my fifth semester or more.

18. How did you satisfy the prerequisite for this class? (leave blank for Developmental Students)

- ☐ I passed MATD 0390 (with a C or higher) at ACC or I passed an equivalent class at another school.
- ☐ I scored at least a 69 on the algebra COMPASS on my first try.
- ☐ I scored 270 or higher on the THEA exam.
- ☐ I scored at least 570 on SAT math and I took Algebra II in high school.
- ☐ I scored at least 21 on ACT math and I took Algebra II in high school.
- ☐ I'm not sure.

***19. How many times have you taken this class, including this one?**

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5+

***20. What is your overall college GPA (including developmental classes)?**

- ◯ 3.6 - 4.0
- ◯ 3.1 - 3.5
- ◯ 2.6 - 3.0
- ◯ 2.1 - 2.5
- ◯ 2.0 or below
- ◯ I don't know.

***21. What is the highest degree you intend to earn?**

- ◯ Certificate
- ◯ Associate degree
- ◯ Bachelor degree
- ◯ Graduate degree (Master or Doctorate)
- ◯ Other

***22. What is your desired major?**

***23. What is your gender?**

- ◯ male
- ◯ female

***24. Which category below includes your age?**

- ◯ 17 or younger
- ◯ 18-19
- ◯ 20-24
- ◯ 25-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ 60 or older

25. What is the name of this math course?

- ◯ Basic Math Skills
- ◯ Elementary Algebra
- ◯ Intermediate Algebra
- ◯ College Algebra

***26. Who is your instructor?**

***27. What is your section number?**

BASIC MATH FINAL EXAM

Retyped for brevity (original had space for student work).

1.
    a. Express 28 as a product of prime factors.
    b. Express 36 as a product of prime factors.
    c. Find the LCM of $28x^2$ and $36x$.
2. Translate the following into mathematical symbols.
    a. Four ***less than*** a number.
    b. Five times the sum of a number and three.
    c. Fifty-four ***is less than*** five hundred four.
3. Perform the operations indicated.
    a. $-15 - 3 + 12 - (-6)$
    b. $(-6)(2)(-1)(5)(-3)$
4. Evaluate.
    a. $36 + 18 \div 3^2 - 3$
    b. $7 - 2(12 - 15)$
5. Perform the indicated operations. Simplify your answer, if possible.
    a. $\frac{3}{4} - \frac{5}{6}$
    b. $\frac{7}{9} \cdot \frac{3}{5}$
6. Perform the indicated operations. Simplify your answer, if possible.
$\left(\frac{2}{3}\right)^2 + \frac{2}{9} \div \frac{1}{3}$
7. The pep club has $15\frac{1}{3}$ feet of paper on a roll used to make banners. The club must make 3 banners, each $3\frac{1}{4}$ feet in length. (Write your answers as mixed numbers and include proper units.)
    a. How much paper is needed to make the 3 banners?

b. How much paper will be left on the roll after the club makes the 3 banners?

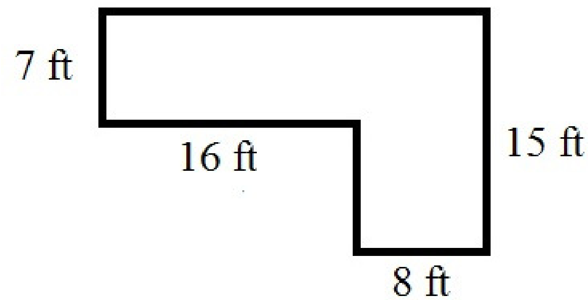
8. Evaluate $\frac{x^2-y}{3}$ for $x = -4$ and $y = -2$.

9. Simplify.

   a. $(-3x)(4y)(2x)$

   b. $\frac{15xy^3}{27y^5}$

10. Consider the following shape made up of rectangles below. (Your answers should include proper units.)

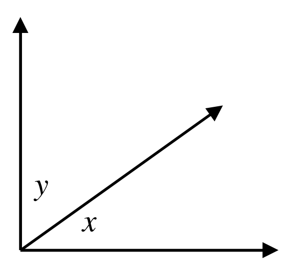


   a. Find the perimeter.

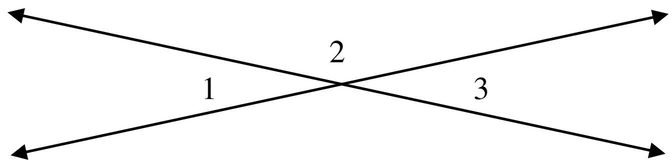
   b. Find the area.

11.

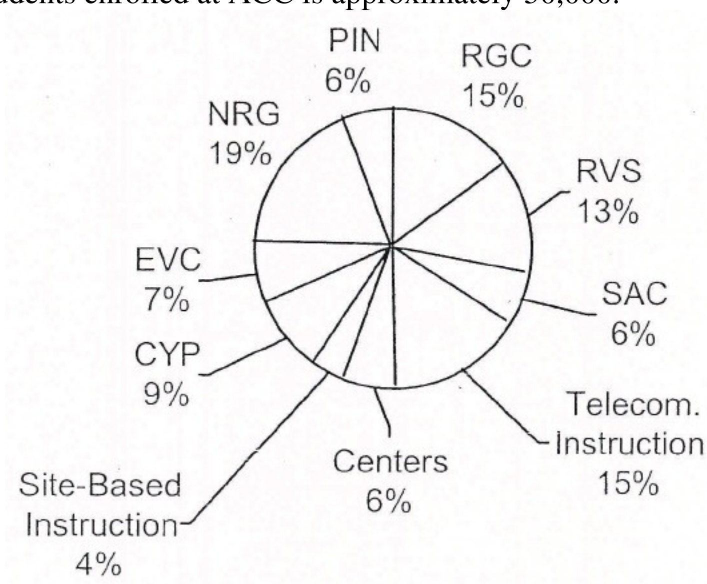
   a. Angle x and y are complementary. If angle y measures 56°, find the measure of angle x. (Your answer should include proper units.)



   b. Find the measures of angles 1 and 2 in the figure below, if the measure of angle 3 is 32.4°. (Your answer should include proper units.)



12. A manufacturing company found that for every 75 parts made, 2 were defective. Based on this information, how many parts are expected to be defective if the company makes 450 parts in one week?
13. The Spring 2009 ACC student headcount enrollment by location is shown in the circle graph below. Use this graph to answer the following questions, if the total number of students enrolled at ACC is approximately 50,000.



   a. How many of the 50,000 students are enrolled at RGC?
   b. Approximately how many more of the 50,000 students are enrolled at CYP than EVC?
14. The ages of six people swimming laps at the YMCS pool one morning were 48, 70, 18, 32, 13 and 77.
   a. Find the mean of their ages.

b. Find the median of their ages.

15. Alex buys a computer for $1100. If the sales tax is 7.5%, what is Alex's total bill? (Your answer should include proper units.)

16. Perform the operations indicated.

    a. $(-3)^2$

    b. $7 \div 0$

    c. $2^3 \cdot 2^5$

    d. x^0

17. Perform the operations indicated.

    a. $7x - 3(x - 2)$

    b. $(8y^2 - 4y + 2) - (5y^2 - 3y + 7)$

18. Simplify.

    a. $7(x - 8)$

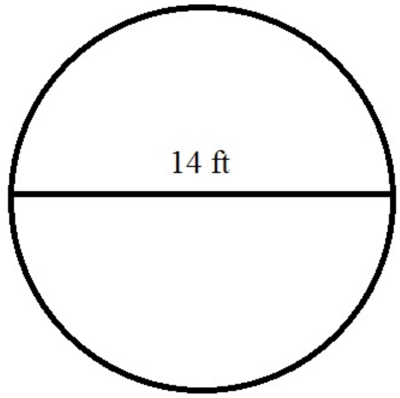
    b. $7(8x)$

19. Solve. $7(x - 8) = 2x - 2$

20. Solve. $0.25x - 0.65x = 6.6$

21. Solve. $4x + \frac{1}{3} = \frac{5}{6}$

22. What is the area of the circle below, with *diameter* 14 feet? Round your answer to the nearest tenth using $\pi \approx 3.14$. The formula for area of a circle is $A = \pi r^2$. (Your answer should include proper units.)



23.

a. Write $\frac{3}{8}$ as a decimal.

b. Write 3.4 as a percent.

c. Write 0.42 as a fraction in simplest form.

24. Refer to the following for 24a and 24b.

If a number is increased by four, the result is thirty-eight. What is the number?

a. Write an equation.

b. Solve the equation.

25. The perimeter of a triangle is 19 feet. The first side is four feet longer than the second. The third side is triple the length of the second side. Find the length of each side of the triangle.

a. Define variable expressions for the length of each side.

b. Write an equation.

c. Solve the equation, and determine the length of each of the sides. (Your answers should include proper units.)

College Algebra Final Exam (Selected Problems)

Lecture Sections

Part 1 #2

Find the slope-intercept equation of a line perpendicular to $2x - 3y = 5$ and passing through the point $(-4, 1)$.

Part 2#8a&b

There are initially 4000 bacteria per millimeter in a sample, and after 1 hour their concentration increases to 6000 bacteria per milliliter. Assume they grow exponentially.

a) Find C and a so that $f(x) = Ca^x$ fits the bacteria's growth.

b) How many bacteria are there after 2.5 hours?

Part 2 #5

There are 2000 tickets sold to a Round Rock baseball game. Adult tickets are \$8 and children's tickets are \$3. If the total revenue at the box office was \$12,000, how many adult tickets and children's tickets were sold?

Part 2 #7

Use properties of logarithms to write the expression as a logarithm of a single expression.

$$\log x - 3\log y + 2\log z$$

Part 2 #6

Solve. $4e^{2x} - 5 = 4$.

Student-led Sections

#1 (only part c was analyzed)

Use the table below to answer the questions about $f(x)$.

x	-2	0	2	4
$f(x)$	8	5	2	-1

(a) Graph the given points of $f(x)$ on the axis provided.

(b) Could $f(x)$ represent a linear function?

(c) If you answered YES to part (b), write $f(x)$ in the form $f(x) = ax + b$. If you answered NO, write N/A.

#4

Find the equation for an exponential function, $f(x)$, that satisfies $f(0) = 4$ and $f(1) = 12$.

#6

A certain movie theater charges $10 for adults and $5 for children. During a particular show, 100 people attended and the theater sold $820 in tickets. How many children and adults attended the movie?

#7

Use the properties of logarithms to write the expression as one logarithm.

$$12 \log_3 \sqrt[4]{x} - \log_3 x$$

#8

Solve the following exponential equation: $3^{x+3} = 7^x$.

CLASSROOM OBSERVATION PROTOCOL

Cover Sheet, Summary, and Classroom Observation Post-Survey

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: **Course:** Basic/Elem/Int/Coll Alg **Observer:**

Class start time: **Instructor:** **Instructor ID:**

Class end time: **Section ID:**

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start					
Entering later					

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

Classroom Observation Post-Survey

Fill out this survey right after observing a class. It aims to capture some general features to complement the detailed log. Use your own assessment based on what you saw and experienced, using the scale (1 = Never to 5 = Very often) to indicate the extent to which the activity or feature occurred in the session you saw. Please add any explanatory comments.

A. What percentage of students (approximately) participated in class? (circle one)

0-25%   25-50%   50-75%   75-100%

Was participation generally representative by gender and ethnicity?   Yes   No
Please comment.

B. To what extent did (single or groups of) students…	**Never**				**Very Often**
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	**Never**				**Very Often**
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

CLASSROOM OBSERVATION LOG

Classroom Observation Log

Date: **Course:** Basic/Elem/Int/Coll Alg **Observer:** Page _____ of _____

Class start time: **Instructor:** **Instructor ID:**

Class end time: **Section ID:**

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
	B L E G P D I C H Q	f s ns rs g c	
	B L E G P D I C H Q	f s ns rs g c	
	B L E G P D I C H Q	f s ns rs g c	
	B L E G P D I C H Q	f s ns rs g c	
	B L E G P D I C H Q	f s ns rs g c	
	B L E G P D I C H Q	f s ns rs g c	
	B L E G P D I C H Q	f s ns rs g c	

What's the main activity going on?

B Addressing class <u>business,</u> procedural activity or information (e.g. returning papers)

Examples: Giving homework or a class assignment, giving directions or guidelines for class work, returning or commenting on exam papers, discussing deadlines. Students or instructor may introduce business. Often happens at the start of class. Once it goes into mathematical content in any significant way, it's probably not business any more.

L <u>Lecturing</u>—Professor presenting pre-prepared material.

The key here is that the instructor is in charge and is presenting previously organized material, not necessarily responsive to students, although it may include some Q&A as part of the lecture. Most of what is going on is "telling."
- Examples: Presenting/explaining general strategies or ideas about mathematics; instructor working "example problems".
- To think about: - How does this differ from explaining?

E <u>Explaining</u> or discussing specific definition, concepts or problems.

This may be done by students or instructors. Key difference from lecturing is spontaneity –this is in response to a difficulty or question –e.g. an impromptu mini-lecture to resolve a class difficulty encountered in group work. May be part of guiding discussion but is a more extended commentary of some kind – a takeover of class for a time.
- Examples: Explaining the main issues in a task, explaining the "big" ideas of a topic or a problem, explaining a mathematical principle, explaining a solution (note that this is different from an instructor working problems for the sake of having examples).
- To think about: - How does this differ from lecturing?

G Working in <u>groups</u>

Groups may be working on a problem or an example, discussing a reading or handout, discussing or critiquing a solution. Students may be in their seats or at the board. Board work is informal – e.g. multiple groups working in parallel at the board, rather than one group present at the board. Instructor may be observing or interacting with individual groups—is not trying to present to all.
- To think about: - Is it important to separate between whole class working on a problem and small group working?

P Students <u>presenting</u> a solution *(individuals or groups).*

This is more formal presentation by a person or group – may be prepared in advance or during class, but a student or group of students is in control of the presentation.
- To think about: What if instructor or TA is presenting a solution or a proof? (I would consider this L.)

D Class <u>discussing</u> a concept or argument, critiquing a solution that has been/is being presented.
A whole-class activity – small groups coming back together to discuss solutions, class critiquing a presented solution, etc. Some classes go back and forth very quickly between S and D (so –S/D) while others hold off on D until S is done.
- To think about: - How does this differ from group work on a problem (G)?

I Students are working on problems <u>individually</u>.
Students are working problems at their seats individually. While they might occasionally talk to other students, they are not in formal groups (G) and most are working by themselves.

C The instructor is actively <u>circulating</u> the room.
This may include monitoring student work, correcting students, clarifying questions students have, or helping students to work problems. Most interactions are between the instructor and individuals or the instructor and one group, rather than the entire class (E). Students may be in groups (G) or working individually (I). This will usually be noted as G/C or I/C.

H The instructor is working <u>homework</u> problems on the board.
This includes problems that either the instructor and/or students have chosen. It is different than example problems during a lecture. During H, the main goal is to work through previously assigned problems rather than using examples to develop ideas throughout a lecture.

Q The students are taking a <u>quiz</u> or other assessment.
This category includes quizzes, tests, or other assessments given during class.

Who is taking the lead role?

f Faculty or lead instructor
s Single student
ns New student (first time to participate today)
rs Repeat student (has already participated today)
g Group of students
c Whole class/multiple roles

Appendix B: Observation Data

OBSERVATION SUMMARY

Section ID	Course Title	Instruction Method Classification	Minutes Spent on Classroom Activities									Total Class time in Minutes	Instructor-led Activities	Student-led Activities	% of students observed participating
			B	L	E	G	P	D	I	H	Q				
6538	Basic Math	Lecture	2	48	0	0	0	0	0	11	8	69	86%	0%	50-75%
6525	Basic Math	Lecture	6	60	0	0	0	0	29	0	0	95	63%	0%	50-75%
6531	Basic Math	Lecture	16	49	0	0	0	0	35	0	0	100	49%	0%	50-75%
6545	College Alg.	Lecture	1	46	0	0	0	0	0	14	19	80	75%	0%	25-50%
6512	Basic Math	Student-led	3	48	0	28	10	3	11	0	0	103	47%	40%	75-100%
6504	Basic Math	Lecture	12	43	4	0	5	10		18	8	100	65%	15%	25-50%
6494	Basic Math	Lecture	9	66	0	0	3	9	0	11	9	107	72%	11%	50-75%
6528	College Alg.	Student-led	1	35	21	38	0	0	0	0	0	95	59%	40%	75-100%
6519	College Alg.	Lecture	2	55	0	0	0	0	0	12	12	81	83%	0%	25-50%
6523	College Alg.	Lecture	2	51	0	0	0	0	0	17	11	81	84%	0%	25-50%
6500	Basic Math	Student-led	2	18	6	52	0	0	0	17	10	105	39%	50%	75-100%
6520	College Alg.	Student-led	0	10	0	29	18	14	3	0	0	74	14%	82%	75-100%
6543	College Alg.	Student-led	3	17	2	68	10	0	0	0	0	100	19%	78%	75-100%

Classroom Activity key:

B: class business
L: lecturing
E: explaining
G: group work
P: student presentation
D: class discussing
I: students working individually
H: instructor working homework problems
Q: quiz or other assessment

COMPLETED OBSERVATION PROTOCOLS

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 04/30/2012 **Course:** Basic **Observer:** Stephanie Peacock

Class start time: 10:15 am **Instructor ID:** 3979

Class end time: 12 pm **Section ID:** 6494

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	5	3	2	2	12
Entering later	1 (arrived at 11:11)	1			2

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

F provides direct instruction in a meaningful way. I would rate him as a very good instructor. The students seem very comfortable asking questions and he listens to their responses, commenting about them in a respectful way. The students don't seem concerned that they may give a wrong answer. There are a few students that joke around a bit but they do not interrupt the flow of the class. Students volunteer when asked if people want to put up problem solutions even thought they don't talk much otherwise. About 30% respond during Q & A quite a bit. It appears as though F tries to have them think about problem situations before moving on to the solution. F pays careful attention to vocabulary and the meaning of formulas. At least half of the students really seem to know what is happening and they provide answers quickly. What other students understand is unclear since they don't speak much.

Classroom Observation Post-Survey

Fill out this survey right after observing a class. It aims to capture some general features to complement the detailed log. Use your own assessment based on what you saw and experienced, using the scale (1 = Never to 5 = Very often) to indicate the extent to which the activity or feature occurred in the session you saw. Please add any explanatory comments.

A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% <u>50-75%</u> 75-100%

Was participation generally representative by gender and ethnicity? <u>Yes</u> No
Please comment.
Two of the 4 students of color participated. The male talked quite a bit but was normally on topic. He asked questions and answered questions. He had already done the homework over today's topic. He thought it was assigned. 4 of the female students verbally participated and 4 of the male students verbally participated.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	<u>4</u>	5
2. Ask instructor/TAs questions?	1	2	3	<u>4</u>	5
3. Review or challenge other students' work?	<u>1</u>	2	3	4	5
4. Work together with other students?	<u>1</u>	2	3	4	5
5. Set the pace of direction of class time?	<u>1</u>	2	3	4	5
6. Get help from other students?	<u>1</u>	2	3	4	5
7. Receive personal feedback on their work?	1	<u>2</u>	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	<u>4</u>	5
2. Express their own ideas or solutions to problems?	1	2	3	4	<u>5</u>
3. Set the pace or direction of class time?	1	2	3	4	<u>5</u>
4. Give concrete feedback on students' work?	1	<u>2</u>	3	4	5
5. Offer help to students? NOTE: #5 IS DURING Q & A	1	2	3	<u>4</u>	5
6. Establish an overall positive atmosphere?	1	2	3	4	<u>5</u>
7. Summarize or place class work in a broader context?	1	2	<u>3</u>	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
10:13	B L E G P D I C H Q 3 minutes	f s ns rs g c	F tells students they will take a quiz over previous stuff (things they covered in their homework). A student asks if it will cover 10.5. F says no b/c they haven't covered that yet. They will cover it today. The student says he already did those homework problems. F says, "Well, that's good. You are ahead of the game." Student says, "Awww. I thought I was doing something good." He seems a little annoyed that he had already done the work.
10:16	B L E G P D I C H Q 5 minutes	f s ns rs g c	F: Any questions over 10.1? It was about conversions in the metric system. Goes through quick review. Does a little Q & A.
10:21	B L E G P D I C H Q 4 minutes	f s ns rs g c	Quiz over the 10.1. F is not going to collect this. F just wants them to work on it to see if they can figure it out. A couple of students are talking briefly but stop. F is passing out previous work (maybe homework??)
10:25	B L E G P D I C H Q 2 minutes	f s ns rs g c **There are 3 students that do this. Others are finishing up or looking at the solutions.**	F: Do some people want to put these on the board? Students volunteer, writing their solutions to the 3 problems. There are 2 female and 1 male volunteers. The solutions show some work. Not much work is required in these problems.
10:27	B L E G P D I C H Q 5 minutes	f s ns rs g c	F: Okay, let's go through this. F explains what the students did. F notes that it is important to include the units in the conversion problems (which the student did). F notes that .750 km is a fine way to write the solution and that he wouldn't count it wrong. F

			says that, in the nursing program, they may count it wrong since they are mostly worried about the 0 in the front (i.e., 0.750 kg). F also notes that is okay to write 0.750 even though the last 0 isn't needed.
10:32	B L E G P D I C H Q 6 minutes	f s ns rs g c	F: Questions about 10.3 homework? F: if that one is 39 degrees, what angle is that? Ss: 39. F: That is correct, can you tell me why? F says that opposite angles are equal. F goes into finding angles inside a triangle. Asks students how they would figure it out. Female student responds 39 + 90 + the other angle is 360. F: That's almost correct. Student corrects herself saying 180. F writes the problem: 39 + 90 + <w = 180 129 + <w = 180 -129 -129 <w = 51 F using vocabulary. (e.g., angles, supplementary, complementary, Alternate interior, corresponding, transversal, etc.)
10:38	B L E G P D I C H Q 5 minutes	f s ns rs g c	Quiz over the 10.3. F is not going to collect this. F just wants them to work on it to see if they can figure it out. F explains that he has probably given them enough feedback. F says, "The important thing is that you are writing these down and you understand for the exam." A couple of students are talking briefly but stop. F tells them that he doesn't need them to show it a certain way but he "would probably use an equation on number 3."
10:43	B L E G P D I C H Q 1 minute	f s ns rs g c **There are 3 students that do this. Others are finishing up or looking at the solutions.**	Need a volunteer for 3. What about 1? (male student volunteers but F says he wants someone else to do it b/c he presented on the first quiz). How about 2? There were 2 female and 1 male volunteers for the total of 3 problems. Note that students volunteer quickly. Students more work than on the previous quiz. There is more work required on these b/c they had to draw pictures.
10:44	B L E G P D I C H Q 4 minutes	f s ns rs g c	F explains what the students did in their solutions. F carefully uses vocabulary again (e.g., adjacent angles, etc.).

10:48	B L E G P D I C H Q 6 minutes	f s ns rs g c	Have you guys signed up for classes for the summer? Students seem unsure about what classes to sign up for. F: If you have a 70 or above right now, I would say you could probably sign up for the next class. If you have any questions about that, you can come see me. There is no problem with taking a class over again, except for maybe financial aid. So, you may want to check with them. It is okay with the math department. You can take it as many times as you want. Student shares what he knows about the financial aid implications (mentions stuff about IP progress). F reminds them that the test window ends tonight so they need to do that and not miss the window. Student asks about when the department final will be. F tells them that it will be in class, not online (like the tests normally are). F tells them that they can stay late on the final if they want. F tells them they can only use a 4 function calculator.
10:54	B L E G P D I C H Q	f s ns rs g c	F: Let's look at 10.5. We only have 3 sections left: Circle, volume, and then we look back at similar figures and proportions. F lectures about radias (label it r), diameter (label it d). The lecture involves a lot of Q & A. F: Most of these formulas for now on out you won't have to memorize because you will be given a formula sheet. However, you do need to memorize this one, that the diameter is twice the radius. F: The perimeter of a circle has a special name. Does anyone know what that is? Student responds: Circumference. F: There is a formula for circumference: $c = \pi d$. F explains that 3.14 is just an approximation that they will use in class and π is an infinite number. F relates topic to real world applications. F explains that you can divide both sides by d. F: So, π = circumference over diameter. This is another way of thinking about what π is. It's a ratio. Whenever you divide the circumference by the diameter, you will always get something close to 3.14.

	66 minutes		F works through some examples, telling the students that these should be pretty easy to do since they can do them on their calculators. F constantly asks questions that are meant to get them to think about the size of things (e.g., What's the size of a meter? How big is that?). He gives examples such as the distance between him and the wall and imagining if there was a circle where the center was the center of the classroom. F (problem about 2 differently sized wheels and revolutions they make): I don't think you are going to have a problem like this on the final, but you will have one on your homework. F describes the problem with his arms, showing the small wheel and the bigger wheel. F tries to have them think about it before moving on to the solution. F talks through much of the problem solution. F relates the situation to bicycles. F continues the lecture in similar fashion as above. At 11:35, they move on to Section 10.6 on volume. F: We've talked a little about volume before, such as when we talked about rectangular solids. F reviews dimensions/formulas for rectangular solids (V=LWH). He talks about measuring the classroom. F labels his drawing with the approximations the class decided on. F did this to point out the importance of keeping the units in mind. F reminds them about what a cubic foot would look like and how they would be stacked in the room. F continues lecture in the same fashion as above. F provides conceptual explanation about how the formulas were created but notes again that they will be provided on the exam. F: It will say, "use this formula in this problem." At 11:52, F works some example problems.
12:00	<u>B</u> L E G P D I C H Q Class is over.	<u>f</u> s ns rs g c	F: Okay, we didn't quite finish this, but try these out at home.

12:02	B L E G P D I C H Q	f s ns rs g c	When there are only 2 students left, one asks if he will accept her "really late" homework. F says he will even though "it is really late." F says it will be 10% off and student says that is fine.

Total class time: 107 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/18/12 **Course:** Basic Math Skills **Observer:** Cyntreva Paige

Class start time: 10:55 am **Instructor ID:** 3998

Class end time: 12:40 pm **Section ID:** 6500

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	5	3			8
Entering later		1			1

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

Overall morale was good. Instructor seemed to check for understanding a lot. Students participated throughout.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% 75-100%

Was participation generally representative by gender and ethnicity? Yes No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
10:55	B L E G P D I C H Q 10 minutes	f s ns rs g c	Students spent first 10 minutes on individual quiz.
11:05	B L E G P D I C H Q 11 minutes	f s ns rs g c	Students took a group quiz.
11:16	B L E G P D I C H Q 17 minutes	f s ns rs g c	F asked for questions about HW and reviewed operations with decimals. Students were interacting with F as F asked questions. At one point a student requested that a particular problem be worked. F asks lots of questions, students are fairly responsive. One female student is very vocal and often answers/asks questions.
11:33	B L E G P D I C H Q 2 minutes	f s ns rs g c	F moved on to lecturing over new material.
11:35	B L E G P D I C H Q 41 minutes	f s ns rs g c	Ss worked in groups of 2-3 on new material – worksheets designed by F.
12:16	B L E G P D I C H Q 6 minutes	f s ns rs g c	F brings students together to summarize decimal/fraction/percent conversions. This is summarizing ideas in a broader context. Ss asked questions throughout and were overall responsive to F's questions.
12:22	B L E G P D I C H Q 16 minutes	f s ns rs g c	This was more of a game plan for the next section's worksheet. F was the main person doing the "telling" though.

12:38	B L E G P D I C H Q 2 minutes	f s ns rs g c	F reminded students about HW and passed out an optional worksheet.

Class ended at 12:40.

Total class time: 105 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/25/2012 **Course:** Basic **Observer:** Stephanie

Class start time: 10:55 am **Instructor ID:** 4000

Class end time: 12:40 pm **Section ID:** 6501

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	4	2	2	2	10
Entering later					0

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

The students seem to feel very comfortable asking questions. When the instructor is responding to questions, f provides concrete feedback and answers directly or provides suggestions. F always has positive comments thrown in with more corrective comments, highlighting strengths while helping students correct errors or move forward when stuck. Many suggestions f provides are about problem setup. F asks the students questions when helping them individually or in groups (e.g., "So, what does [this (pointing to something specific)] mean? F asks students for justifications and requires them to explain their reasoning.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25%   25-50%   50-75%   75-100%

Was participation generally representative by gender and ethnicity?   Yes   No
Please comment.
Note that one female student did not participate in any discussion or group work but did do the work on her own. She is the female that answered the quick question (below) by a male student.

B. To what extent did (single or groups of) students…	**Never**				**Very Often**
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	**Never**				**Very Often**
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
11:00 am *Class started late.	B L E G P D I C H Q 3 minutes	f s ns rs g c	Passed back tests.
11:03	B L E G P D I C H Q 9 minutes	f s ns rs g c	Lecture about volume.
11:12	B L E G P D I C H Q 8 minutes	f s ns rs g c	Lecture about similar figures. Used powerpoint and drew pictures on the board.
11:20	B L E G P D I C H Q 50 minutes	f s ns rs g c	Students working on problems in groups over Section 10.6. All groups continue to work together throughout this time period unless otherwise specified. Groups: **3 female** **1 female** **1 female** **2 male** **1 male** - At 11:35, he joined the group of 2 males at the instructor's urging. **1 male and 1 female** – looked at returned test until 11:30 F is actively circulating. F answers problems directly and provides suggestions related to problem setup. F does a lot of E (explaining) while circulating. One female that is working alone answered a question asked by the male working with the female. This was a very brief exchange. At 11:50, students still in groups but female in

			the 3 female group writes a solution on the board. At 11:51, male from the 1 male and 1 female group volunteers and writes a solution on the board (without f prompting for volunteers). One male in the 3 male group volunteers to write a solution. At 11:55, f tells class that they should look at the board to see if they got the same answer (if they are done with the problems). At 11:55, another male from the 3 male group writes a solution on the board. At 12:01, female from 2 female group writes solution on the board.
12:10 pm	B L E G P D I C H Q 10 minutes	f s ns rs g c	Instructor asks for presenters (of their own work). The students that wrote the solutions on the board quickly walk everyone though their processes of solving the problems. Instructor asks if everyone got the same and answer and question such as "what do you think?" Some students get up when they are walking students through their problems while others remain at their seats. Instructor mainly interrupts only to correct notation or ask for precision in their math vocabulary (e.g., squared vs. cubed and "divide what by 2?"). After students present, instructor provides a few math comments. Instructor also comments on positive aspects of the way student solved problems or presented. There is constant positive reinforcement. Then everyone claps for the presenter.
12:20	B L E G P D I C H Q 18 minutes	f s ns rs g c	Students go back to work in the same groups as before. Some are working on a new section while others are working on application problems in the current section. At 12:30, student writes solution on the board without instructor prompting. At 12:35, female (in 1 female and 1 male group) puts her stuff away, preparing to leave class. At 12:38, more students start prepping to leave. Instructor reminds them that they have a little more time.
12:38	B L E G P D I C H Q ??? 2 minutes	f s ns rs g c	Instructor notes that they are almost out of time and, hence, presents the last solution that has been written on the board by a student. Instructor explains that there is more than one way to set up the problems/solutions (The student's solution setup was correct but it was not the only way it could be done). The instructor uses precise vocabulary when

			explaining the problem.

Class ended at 12:40.

Total class time: 100 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/30/2012 **Course:** Basic **Observer:** Stephanie Peacock

Class start time: 12:10 pm **Instructor ID:** 3979

Class end time: 1:55 pm **Section ID:** 6504

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	5	4			9
Entering later	1	2		1	4

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

This class felt very similar to his previous class at 10:15 (also Basic Math). The main difference was that the energy wasn't as high. They seemed a little sluggish (maybe an after lunch thing). Most students seemed to be paying attention but they looked tired (and yawned several times☺). They still responded in Q & A. They didn't volunteer many comments or ask as many questions as the previous class. However, they did both of these.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% 75-100%

Was participation generally representative by gender and ethnicity? Yes No
Please comment.

Responses were short and to the point but came from males and females. There were not a lot of responses from the students of color.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
12:10	B L E G P D I C H Q 1 minute	f s ns rs g c	10.1 was due Wednesday and 10.3 is due today. F introduces me (the observer☺)
12:11	B L E G P D I C H Q 7 minutes	f s ns rs g c	Any questions before the quiz? Goes through a quick review and does a little Q & A.
12:18	B L E G P D I C H Q 4 minutes	f s ns rs g c	Quiz over the 10.1. F is not going to collect this. F just wants them to work on it to see if they can figure it out. F is passing out previous work (maybe homework??). One student asks about tomorrow's office hours and says he will probably go by to talk to him.
12:22	B L E G P D I C H Q 2 minutes	f s ns rs g c **There are 3 students that do this. Others are finishing up or looking at the solutions.**	F asks for student volunteers to write the solutions on the board. 1 male and 2 female volunteer and write their solutions on the board. They show their work but their isn't much of it (b/c not much work needs to be shown for these types of problems).
12:24	B L E G P D I C H Q 5 minutes	f s ns rs g c	F: Alright. Let's check these out. Did you all get 1440 on #1? One student says yes. F: Remember, if you want to use the unit fraction method, you… F mentions a song (from Rent) about seconds in a year (maybe). He couldn't remember if it was a year, a month, or something else. He says they could figure those things out using this

			method. The students are all trying to remember the song. One student checks the internet so they can verify the conversion. F moves on to the next problem and notes that .750 km is a fine way to write the solution even though the end 0 is not needed. He also says that it can be written as 0.750 or 0.75.
12:29	B L E G P D I C H Q 2 minutes	f s ns rs g c	Student asks about when their folders are due. This leads to a brief discussion about logistics for the final exam.
12:31	B L E G P D I C H Q 4 minutes	f s ns rs g c	The student that was looking for the conversion with seconds in the Rent song found the lyrics and shares. They do the conversion. One student says, “What if it’s a leap year?” F has them take the average of 365 + 365 + 365 + 366 to figure out something more accurate.
12:35	B L E G P D I C H Q 11 minutes	f s ns rs g c	F: Questions about 10.3 homework? F works homework problems. This involves some Q & A. F makes students explain their responses. F is very encouraging. When someone gets half of the answer right or is on the right track, he lets them know they are on the right track.
12:46	B L E G P D I C H Q 4 minutes	f s ns rs g c	Quiz over the 10.3. F is not going to collect this. F just wants them to work on it to see if they can figure it out.
12:50	B L E G P D I C H Q 3 minutes	f s ns rs g c **There are 3 students that do this. Others are finishing up or looking at the solutions.**	F asks for volunteers to put up solutions from Quiz 10.3. 2 male and 1 female volunteer and write their solutions to the 3 problems.
12:53	B L E G P D I C H Q 5 minutes	f s ns rs g c	F explains what the students did in their solutions. F explains the importance of including the units and writing the work correctly. One student wrote 72 – 180 = 108. F said it should be written as 180 – 72 = 108. F said he knew what the student meant but they need to be careful to write these things in the correct way. At 12:56, male student of color walks in.

			F explains the last problem.
12:58	B L E G P D I C H Q 4 minutes	f s ns rs g c	Student asks why they don't cover square roots in this class. He explains that they have too much information to cover so the department decided to include them in the next class. There is a brief discussion about what he is teaching in the summer. A student was asking whether or not he would be teaching the following class (Elementary Algebra) in the summer. He said he would be teaching it in the second session. It is the 5.5 week class (super fast). He said that a lot of people would say not to take that class because it is too fast. He said he thinks it can be a good thing as long as you aren't taking other classes or working a lot.
1:02	B L E G P D I C H Q 29 minutes	f s ns rs g c	10.5 Lecture. This is the same lecture as in his previous class on 4/30/2012 (observed by Stephanie Peacock) and it has the same "feel". It's instructive but has a lot of examples that are really visual and the students seem interested for the most part. The section ID for that class is 6494. Refer to those notes for additional information.
1:31	B L E G P D I C H Q 4 minutes	f s ns rs g c	F told a student to put away his cell phone, to take it off his desk completely. The student was somewhat defiant and this led to a strange change in the class's mood. There was a cloud of anxiety/surprise/etc. in the air. Everyone seemed to be holding his or her breath. Lecture continued.
1:35	B L E G P D I C H Q 1 minute	f s ns rs g c	It seems as though the cloud has mostly lifted but it is still floating around for some of the students (especially the one that was reprimanded). F has tried to keep the mood light.
1:36	B L E G P D I C H Q 14 minutes	f s ns rs g c	10.5 Lecture continued. At 1:44, 10.6 lecture begins.
1:50	B L E G P D I C H Q	f s ns rs g c	F says they are out of time and class is released. Is this early? My materials said 1:55.

Total Class time: 100 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/10/12 **Course:** Basic Math Skills **Observer:** Cyntreva Paige

Class start time: 2:45 pm **Instructor ID:** 3977

Class end time: 4:30 pm **Section ID:** 6512

Description of student population <u>counted</u> or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	3	3			6
Entering later					

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

Most students (5 of 6) were participating and working the problems along with the instructor. Several students expressed concerns of being "behind" at the beginning of class. F seems to have a good rapport with the students – like they are in it together.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% <u>75-100%</u>

Was participation generally representative by gender and ethnicity? <u>Yes</u> No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	<u>3</u>	4	5
2. Ask instructor/TAs questions?	1	2	<u>3</u>	4	5
3. Review or challenge other students' work?	1	<u>2</u>	3	4	5
4. Work together with other students?	1	<u>2</u>	3	4	5
5. Set the pace of direction of class time?	<u>1</u>	2	3	4	5
6. Get help from other students?	1	<u>2</u>	3	4	5
7. Receive personal feedback on their work?	1	2	<u>3</u>	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	<u>2</u>	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	<u>4</u>	5
3. Set the pace or direction of class time?	1	2	3	4	<u>5</u>
4. Give concrete feedback on students' work?	1	2	<u>3</u>	4	5
5. Offer help to students?	1	2	3	<u>4</u>	5
6. Establish an overall positive atmosphere?	1	2	3	4	<u>5</u>
7. Summarize or place class work in a broader context?	1	<u>2</u>	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each <u>change</u>.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
2:47	B <u>L</u> E G P D I C H Q 1 minute	f s ns rs g c	
2:48	B L E G <u>P</u> D I C H Q 4 minutes	f <u>s</u> ns rs g c	
2:52	B L E G P <u>D</u> I C H Q 3 minutes	<u>f</u> s ns rs g c	
2:55	B <u>L</u> E G P D I C H Q 11 minutes	<u>f</u> s ns rs g c	
3:06	B L E G <u>P</u> D I C H Q 6 minutes	f <u>s</u> ns rs g c	
3:12	B <u>L</u> E G P D I C H Q 2 minutes	<u>f</u> s ns rs g c	
3:14	B L E G P D <u>I</u> <u>C</u> H Q 2 minutes	<u>f</u> s ns rs g c	
3:16	B <u>L</u> E G P D I C H Q 22 minutes	<u>f</u> s ns rs g c	

3:38	B L E G P D I C H Q 3 minutes	f s ns rs g c	
3:41	B L E G P D I C H Q 3 minutes	f s ns rs g c	
3:44	B L E G P D I C H Q 3 minutes	f s ns rs g c	
3:47	B L E G P D I C H Q 6 minutes	f s ns rs g c	
3:53	B L E G P D I C H Q 3 minutes	f s ns rs g c	
3:56	B L E G P D I C H Q 3 minutes	f s ns rs g c	
3:59	B L E G P D I C H Q 3 minutes	f s ns rs g c	
4:02	B L E G P D I C H Q 28 minutes	f s ns rs g c	

Class ended at 4:30.

Total class time: 103 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/11/12 **Course:** College Algebra **Observer:** Cyntreva Paige

Class start time: 3:00 pm **Instructor ID:** 3996

Class end time: 4:20 pm **Section ID:** 6519

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	6	11	2		19
Entering later	1		1		2

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

About ½ to 2/3 of the class was paying attention during HW question time. Quiz was planned (not a pop quiz).

During lecture, about 5 students have books open. About 5-10 students respond to questions (low level) regularly. For example, what is the principal, interest, time, etc. in a compound interest formula.

During lecture, one student on laptop. One student asked a question to lead the lecture where the instructor was going. F periodically asks for questions during lecture. He also asks some "thinking" type questions, which a few students answer.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25%   <u>25-50%</u>   50-75%   75-100%

Was participation generally representative by gender and ethnicity? <u>Yes</u> No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	<u>2</u>	3	4	5
2. Ask instructor/TAs questions?	1	2	3	<u>4</u>	5
3. Review or challenge other students' work?	<u>1</u>	2	3	4	5
4. Work together with other students?	<u>1</u>	2	3	4	5
5. Set the pace of direction of class time?	1	<u>2</u>	3	4	5
6. Get help from other students?	<u>1</u>	2	3	4	5
7. Receive personal feedback on their work?	1	<u>2</u>	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	<u>3</u>	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	<u>5</u>
3. Set the pace or direction of class time?	1	2	3	4	<u>5</u>
4. Give concrete feedback on students' work?	1	<u>2</u>	3	4	5
5. Offer help to students?	1	<u>2</u>	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	<u>5</u>
7. Summarize or place class work in a broader context?	1	<u>2</u>	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
3:00	B L E G P D I C H Q 2 minutes	f s ns rs g c	F passed back quizzes and introduced the observers.
3:02	B L E G P D I C H Q 12 minutes	f s ns rs g c	F worked out HW problems on the board.
3:14	B L E G P D I C H Q 12 minutes	f s ns rs g c	Daily quiz (open notes). F wrote formula on board for the day's lecture during quiz. About 85% of Ss were using notes.
3:26	B L E G P D I C H Q 55 minutes	f s ns rs g c	Quick review of formula from last time. Lecture over compound interest building to continuous compounding.

Class end time: 4:21pm

Total class time: 81 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/24/12 **Course:** College Algebra **Observer:** Cyntreva Paige

Class start time: 3:00 pm **Instructor ID:** 4002

Class end time: 4:20 pm **Section ID:** 6520

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	4	7		1	12
Entering later	2				2

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

F seemed to have a good rapport with the students. He was able to call on them by name and they were very responsive. An interesting thing happened while the students were working in groups. One student asked F to leave the logarithm properties on the board during presentations and put a box around them. He (the student) later referred to them during his presentations, as did several others. I thought this showed that the students really valued the flow of a good presentation.

Classroom Observation Post-Survey

Fill out this survey right after observing a class. It aims to capture some general features to complement the detailed log. Use your own assessment based on what you saw and experienced, using the scale (1 = Never to 5 = Very often) to indicate the extent to which the activity or feature occurred in the session you saw. Please add any explanatory comments.

A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% <u>75-100%</u>

Was participation generally representative by gender and ethnicity? <u>Yes</u> No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	<u>4</u>	5
2. Ask instructor/TAs questions?	1	2	3	<u>4</u>	5
3. Review or challenge other students' work?	1	2	3	<u>4</u>	5
4. Work together with other students?	1	2	3	<u>4</u>	5
5. Set the pace of direction of class time?	1	2	3	<u>4</u>	5
6. Get help from other students?	1	2	3	<u>4</u>	5
7. Receive personal feedback on their work?	1	2	3	<u>4</u>	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	<u>4</u>	5
2. Express their own ideas or solutions to problems?	1	<u>2</u>	3	4	5
3. Set the pace or direction of class time?	1	2	<u>3</u>	4	5
4. Give concrete feedback on students' work?	1	2	3	<u>4</u>	5
5. Offer help to students?	1	2	3	4	<u>5</u>
6. Establish an overall positive atmosphere?	1	2	3	4	<u>5</u>
7. Summarize or place class work in a broader context?	1	2	3	<u>4</u>	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
3:01	B L E G P D I C H Q 2 minutes	f s ns rs g c	F led students to review what logarithms are by asking them to write down what $\log_3 7$ means in a complete sentence.
3:03	B L E G P D I C H Q 2 minutes	f s ns rs g c	F circulated the room while students wrote down their answers.
3:05	B L E G P D I C H Q 5 minutes	f s ns rs g c	Class discusses what the correct meaning of $\log_3 7$ is.
3:10	B L E G P D I C H Q 1 minute	f s ns rs g c	F posed three more questions about logarithms for students (more concrete ones with integer answers, for example $\log_3 27$).
3:11	B L E G P D I C H Q 9 minutes	f s ns rs g c	F went on to discuss a few more logarithm examples ($\log_2 64$, $\log_5 25$, etc.). Then F showed examples that led students to guess the following rule: log(ab)=log(a) + log(b). F is at the board, but the majority of what F writes is coming from the students (they say it before F writes it). Toward the end, it starts to seem a little more like L, but students are really still putting forth their own ideas. Impressive!
3:20	B L E G P D I C H Q 3 minutes	f s ns rs g c	F begins to lecture over the next log rule. The students needed more help coming up with this one.
3:23	B L E G P D I C H Q 11 minutes	f s ns rs g c	Students worked in-class problems in groups while F circulated. There was at least one female in each group. F assigned problems for some of the students to work on the board.

3:52	B L E G P D I C H Q 18 minutes	f s ns rs g c	Individual students presented problems from the ones they had been working on. The class sometimes gave feedback on the solutions being presented.
4:10	B L E G P D I C H Q 5 minutes	f s ns rs g c	F talked about how to graph logarithmic functions.

Class ended at 4:15pm (consent forms were collected).

Total class time: 74 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/11/12 **Course:** College Algebra **Observer:** Cyntreva Paige

Class start time: 5:00 pm **Instructor ID:** 3996

Class end time: 6:20 pm **Section ID:** 6523

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	8	4			12
Entering later		1			1

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

Most (about 80-90%) of students used notes during the quiz.

This class seemed a little quieter than F's other section. Much different dynamic!

Thoughout L, instructor asked questions, some were low level (example during H: f(x)=10^x, what is f(2)?), others were more "how" or "why" questions. Students were fairly quiet, so F often answered the latter type himself.

F has clearly made an attempt to learn students' names.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25%   25-50%   50-75%   75-100%

Was participation generally representative by gender and ethnicity?   Yes   No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
5:00	B L E G P D I C H Q 2 minutes	f s ns rs g c	F reminded students about exam; passed back quizzes.
5:02	B L E G P D I C H Q 17 minutes	f s ns rs g c	Students requested HW questions. Approximately ½ of the class was participating/answering questions.
5:19	B L E G P D I C H Q 11 minutes	f s ns rs g c	Daily HW quiz, open notes. F stated that quizzes are returned the following class period. F wrote examples for the lecture on the board during the quiz.
5:30	B L E G P D I C H Q 51 minutes	f s ns rs g c	F has great board work and pauses periodically for questions.

Class ended at 6:21.

Total class time: 81 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/17/12 **Course:** Basic Math **Observer:** Cyntreva Paige

Class start time: 5:40 pm **Instructor ID:** 3973

Class end time: 7:25 pm **Section ID:** 6525

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	3	3	1	3	10
Entering later					

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

About 1/3 to ½ of the students seemed to be working the problems along with F. Almost all had their books open. F interacts very well with the students.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25%   25-50%   50-75%   75-100%

Was participation generally representative by gender and ethnicity?   Yes   No
Please comment.

B. To what extent did (single or groups of) students…	**Never**				**Very Often**
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	**Never**				**Very Often**
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
5:40	B L E G P D I C H Q 6 minutes	f s ns rs g c	F reminded students to go take their exam in the testing student. F also asked if there were any questions.
5:46	B L E G P D I C H Q	f s ns rs g c	F lectured over material, incorporating examples.
6:22	B L E G P D I C H Q	f s ns rs g c	F passed out problems for students to work, but showed the solutions right away. This is why I categorized this as L rather than I. About 2/3 of the students worked along and participated.
6:37	B L E G P D I C H Q 51 minutes	f s ns rs g c	F lectured over the next section.
6:46	B L E G P D I C H Q 29 minutes	f s ns rs g c	F passed out problems for the students to work during class. Some worked in pairs. The answers were also passed out so that students could check their answers.

Class ended around 7:20pm Most students started chatting and stopped working around 7:10pm. Use 7:15 for end time.

Total class time: 95 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/18/12 **Course:** College Algebra **Observer:** Cyntreva Paige

Class start time: 6:15 pm **Instructor ID:** 3989

Class end time: 7:55 pm **Section ID:** 6528

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	1	2		1	4
Entering later	2	1		1	4

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

About ½ of the class was taking notes, but several of those who were not were very interactive. Students seem to like F but are rather bored by the subject material. Students also seemed very tired – I think this is a big challenge for evening classes!

The student mood changed completely when the class switched to group work. All students except for one were working the in-class problems, and the one that was not was participating verbally. Groups were made up of 2-3 students each.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% 75-100%

Was participation generally representative by gender and ethnicity? Yes No
Please comment.

Only 25-50% participated during lecture, but all participated during group work.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
6:15	B L E G P D I C H Q 1 minute	f s ns rs g c	F asked if there were any questions and handed back a few exams.
6:16	B L E G P D I C H Q 35 minutes	f s ns rs g c	F reviewed rules of exponents and transitioned into exponential functions. F then lectured over exponential functions, including compound interest.
6:51	B L E G P D I C H Q 11 minutes	f s ns rs g c	Students worked the in-class problems in groups (theses are problems that are similar to the homework they are assigned after each class).
7:02- 7:04*	B L E G P D I C H Q 2 minutes	f s ns rs g c	F explained an idea to a group of students (pointing at what was on the board from lecture).
7:02	B L E G P D I C H Q Don't count any time here	f s ns rs g c	More group work.
7:04	B L E G P D I C H Q 5 minutes	f s ns rs g c	F clarified an idea for the entire class, and then explained a solution. The class interacted during this time.
7:09	B L E G P D I C H Q 9 minutes	f s ns rs g c	Students went back to working problems in groups. F circulated to answer questions. F often asked students to explain their reasoning.

7:18- 7:20*	B L E G P D I C H Q 2 minutes	f s ns rs g c	F clarified a question about logarithm rules to a group of students (using the board).
7:20	B L E G P D I C H Q 1 minute	f s ns rs g c	Back to group work. F sometimes "explains" to groups of students, using questioning to probe for understanding.
7:21*	B L E G P D I C H Q Don't count any time here	f s ns rs g c	F again used board work from the lecture to explain a concept to 2 groups of students.
7:21	B L E G P D I C H Q 2 minutes	f s ns rs g c	
7:23- 7:24*	B L E G P D I C H Q 1 minute	f s ns rs g c	F clarifies meaning of "ln" on the board – talking to mostly one student, maybe 2-3.
7:24	B L E G P D I C H Q 7 minutes	f s ns rs g c	Again, F was doing some "E" among groups. I only coded "E" when F actually went to the board and was loud enough for more than one group to hear.
7:31- 7:34*	B L E G P D I C H Q 3 minutes	f s ns rs g c	F explained a concept dealing with exponential/logarithmic functions to one group, but another group was interested and also engaged in the conversation.
7:34	B L E G P D I C H Q 1 minute	f s ns rs g c	Students continued working in groups.
7:35- 7:38*	B L E G P D I C H Q 3 minutes	f s ns rs g c	F explained something dealing with the square root function to one group of students.
7:38	B L E G P D I C H Q 5 minutes	f s ns rs g c	

7:43- 7:46*	B L E G P D I C H Q 3 minutes	f s ns rs g c	F explained composition of functions (to one group of students) and how it relates to inverse functions.
7:46	B L E G P D I C H Q 2 minutes	f s ns rs g c	
7:48*	B L E G P D I C H Q 2 minutes	f s ns rs g c	F explained ideas (at the board) about how natural log relates to integrals.
7:50- 7:52*	B L E G P D I C H Q Don't count this – class had already ended.	f s ns rs g c	A student came to the board to write "7^(log$_3$6)" and discussed it with F.

* These activities were occurring simultaneously to the group work.

Class ended around 7:50pm.

Total Class time: 95 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/17/12 **Course:** Basic Math **Observer:** Cyntreva Paige

Class start time: 7:35 pm **Instructor ID:** 3973

Class end time: 9:20 pm **Section ID:** 6531

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	2			1	3
Entering later					

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

A very small class! All 3 students were participating. In particular, two (one female and one male) were talking and asking questions. The other female was paying attention but remained fairly quiet.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% 75-100%

Was participation generally representative by gender and ethnicity? Yes No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
7:35	B L E G P D I C H Q	f s ns rs g c	Only 3 students were present. F chatted with the students and answered a few questions about class business.
7:48	B L E G P D I C H Q 16 minutes	f s ns rs g c	F reminded students about an upcoming exam.
7:51	B L E G P D I C H Q 49 minutes	f s ns rs g c	F presented the material, including working examples.
8:40	B L E G P D I C H Q 35 minutes	f s ns rs g c	F gave students problems to work on at their desks.

Students began leaving around 9:08pm, and class concluded at 9:15pm.

Total class time: 100 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 4/20/12 **Course:** Basic Math **Observer:** Cyntreva Paige

Class start time: 9:20 am **Instructor ID:** 3970

Class end time: 10:30 am **Section ID:** 6538

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start	9	4	1		14
Entering later					

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

Students waited outside until the previous class (same instructor) left. This was at about 9:30. The instructor joked with the students when they came in, asking what they were waiting for. It was a fairly laid back atmosphere, but I thought it was really strange that the other class went over by 15 minutes (only on student left before this) and this one started 10 minutes late.

Overall the students were fairly interactive. I did notice that the older, non-traditional students (about 3) were very quiet.

Classroom Observation Post-Survey

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A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% 75-100%

Was participation generally representative by gender and ethnicity? Yes No
Please comment.

But not by age (older students were quiet).

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
9:32*	B L E G P D I C H Q 11 minutes	f s ns rs g c	F asked if there were any questions over homework. Students requested that 2-3 problems and F worked them on the board.
9:43	B L E G P D I C H Q 8 minutes	f s ns rs g c	Students took a homework quiz – they were allowed to use notes. The quiz was just problems from their homework that they had to recopy (7 minutes for 4 problems).
9:51	B L E G P D I C H Q 2 minutes	f s ns rs g c	F announced that the reviews for the next exam and final are already on Blackboard.
9:53	B L E G P D I C H Q 48 minutes	f s ns rs g c	F lectured over percentages, including working example problems. F asked content questions and asked students if they understood throughout.

*Class did not start until around 9:32.

Class ended at 10:41, at which point F handed out the worksheet for group work next time.

Total Class time: 69 minutes

COVER SHEET and SUMMARY

Classroom Observation Protocol for Mathematics

Date: 9/18/12 **Course:** College Algebra **Observer:** Cyntreva Paige

Class start time: 12:00 pm **Instructor ID:** 4010

Class end time: 1:20 pm **Section ID:** 6545

Description of student population counted or estimated (circle one)

# of students	White women	White men	Women of color	Men of color	TOTAL
Present at start					30
Entering later					

Notes – class context, interactions, mood, morale. What was interesting about this class? Please record what you observed as well as how you interpret it.

Classroom Observation Post-Survey

Fill out this survey right after observing a class. It aims to capture some general features to complement the detailed log. Use your own assessment based on what you saw and experienced, using the scale (1 = Never to 5 = Very often) to indicate the extent to which the activity or feature occurred in the session you saw. Please add any explanatory comments.

A. What percentage of students (approximately) participated in class? (circle one)

0-25% 25-50% 50-75% 75-100%

Was participation generally representative by gender and ethnicity? Yes No
Please comment.

B. To what extent did (single or groups of) students…	Never				Very Often
1. Offer their own ideas during class?	1	2	3	4	5
2. Ask instructor/TAs questions?	1	2	3	4	5
3. Review or challenge other students' work?	1	2	3	4	5
4. Work together with other students?	1	2	3	4	5
5. Set the pace of direction of class time?	1	2	3	4	5
6. Get help from other students?	1	2	3	4	5
7. Receive personal feedback on their work?	1	2	3	4	5

C. To what extend did the instructor and TAs…	Never				Very Often
1. Listen to students' ideas/explanations?	1	2	3	4	5
2. Express their own ideas or solutions to problems?	1	2	3	4	5
3. Set the pace or direction of class time?	1	2	3	4	5
4. Give concrete feedback on students' work?	1	2	3	4	5
5. Offer help to students?	1	2	3	4	5
6. Establish an overall positive atmosphere?	1	2	3	4	5
7. Summarize or place class work in a broader context?	1	2	3	4	5

Classroom Observation Log

Instructions: Mark start time & general activity at each change.

Activity codes: B: class business; L: lecturing; E: explaining; G: group work; P: student presentation; D: class discussing; I: students working individually; C: instructor circulating; H: instructor working homework problems; Q: quiz or other assessment.

Role codes: f: faculty or instructor; s: single student; ns: new student; rs: repeat student; g: group of students; c: whole class/multiple roles

Time	Main activity	Lead role	Notes
12:00	B L E G P D I C H Q 1 minute	f s ns rs g c	F reminds students that there is a quiz at the end of class. F asks if there are any questions over the homework.
12:01	B L E G P D I C H Q 14 minutes	f s ns rs g c	F works two problems from the homework at the students' request.
12:15	B L E G P D I C H Q 46 minutes	f s ns rs g c	F lectured over the material. Students asked a few questions, and F answered them, pointing to the board where the problem had been worked.
1:01	B L E G P D I C H Q 19 minutes	f s ns rs g c	F passes out the quiz. Some students finish quickly (in about 7 minutes) and leave, others take until the end of class and F picks up the quizzes.

Class ended at 1:20.

Total class time: 80 minutes

Appendix C: Final Exam Rubrics

BASIC MATH SKILLS RUBRIC

The abbreviation "S" is used for "student".

<table>
<tr><th rowspan="2">Question</th><th rowspan="2">Objective</th><th rowspan="2">Objective Code</th><th rowspan="2">Score</th><th rowspan="2">Description</th><th colspan="2">Correct answer</th></tr>
<tr><th>Version A</th><th>Version B</th></tr>
<tr><td rowspan="2">3a</td><td rowspan="2">Operations with integers</td><td rowspan="2">1</td><td>0</td><td>S has a mistake somewhere and does not have the correct answer.</td><td rowspan="2">0</td><td rowspan="2">-3</td></tr>
<tr><td>1</td><td>S has the correct answer.</td></tr>
<tr><td rowspan="3">3b</td><td rowspan="3">Operations with integers</td><td rowspan="3">1</td><td>0</td><td>S has one or more mistakes that result in both the sign and the number part of S's answer being incorrect.</td><td rowspan="3">-180</td><td rowspan="3">120</td></tr>
<tr><td>0.5</td><td>S has a mistake on either the sign or the number part, but not both.</td></tr>
<tr><td>1</td><td>S has the correct answer (both sign and number part are correct).</td></tr>
</table>

<table>
<tr><th rowspan="2">Question</th><th rowspan="2">Objective</th><th rowspan="2">Objective Code</th><th rowspan="2">Score</th><th rowspan="2">Description</th><th colspan="2">Correct answer</th></tr>
<tr><th>Version A</th><th>Version B</th></tr>
<tr><td rowspan="7">4a</td><td rowspan="4">Operations with integers</td><td rowspan="4">1</td><td>0</td><td>S did not correctly perform the operations that S attempted.</td><td rowspan="4">35</td><td rowspan="4">14</td></tr>
<tr><td>0.5</td><td>S correctly performed at least one, but not all, of the operations S attempted and has more than one mistake.</td></tr>
<tr><td>0.8</td><td>S has one small arithmetic mistake that makes the answer incorrect.</td></tr>
<tr><td>1</td><td>S correctly performed any operations S attempted (may not have correct answer if S did not follow the order of operations).</td></tr>
<tr><td rowspan="3">Order of operations</td><td rowspan="3">4</td><td>0</td><td>S did not correctly follow the order of operations.</td><td rowspan="3">35</td><td rowspan="3">14</td></tr>
<tr><td>0.5</td><td>S performed the first step in the order of operations correctly (exponents) but did not divide next.</td></tr>
<tr><td>1</td><td>S followed the order of operations, but may not have the correct answer if S made an arithmetic error.</td></tr>
</table>

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
4b	Operations with integers	1	0	S did not correctly perform any of the operations that S attempted.	13	20
			0.5	S correctly performed at least one, but not all, of the operations that S attempted.		
			1	S correctly performed any operations S attempted (may not have correct answer if S did not follow the order of operations).		
	Order of operations	4	0	S did not correctly perform the first step in the order of operations (that is, S did not do the parentheses first or attempt to distribute).	13	20
			0.5	S performed the first step in the order of operations correctly (parentheses) but did not multiply next OR S made a mistake when trying to distribute.		
			1	S followed the order of operations, but may not have the correct answer if S made an arithmetic error.		
5a	Operations with fractions	2	0	S has a mistake somewhere, does not have the correct answer, and did not find equivalent fractions.	-1/12	-1/18
			0.5	S correctly found equivalent fractions with a common multiple but has an arithmetic mistake that prevents S from having the correct answer.		
			1	S has the correct answer.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
5b	Operations with fractions	2	0	S has a mistake somewhere and does not have the correct answer.	7/15	5/12
			0.5	S multiplied correctly but did not reduce the fraction to lowest terms OR S made a mistake when reducing.		
			1	S has the correct answer.		
6	Operations with fractions	2	0	S did not correctly perform any of the operations that S attempted.	10/9	29/16
			0.5	S correctly performed at least one, but not all, of the operations S attempted.		
			1	S correctly performed every operations S attempted (may not have correct answer if S did not follow the order of operations).		
	Order of operations	4	0	S did not correctly follow the order of operations at all - that is, S did not attempt exponents or division as the first step.	10/9	29/16
			0.5	S performed the first step in the order of operations correctly (exponents or division) but did not divide (or do exponents) next. **Note: S does not need to perform the arithmetic correctly to get this score.**		
			1	S followed the order of operations, but may not have the correct answer if S made an arithmetic error.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
7a	Operations with fractions	2	0	S made a mistake, or there is no evidence that S performed the operations that S attempted correctly.	9 3/4 ft	9 3/5 ft
			1	There is evidence (work) that S correctly performed any operations that S attempted.		
7b	Operations with fractions	2	0	S made a mistake, or there is no evidence that S performed the operations that S attempted correctly.	5 7/12 ft	6 11/15 ft
			1	There is evidence (work or a correct answer) that S correctly performed any operations that S attempted. **Note: S may not have the correct answer here if S attempted incorrect operations but performed the operations correctly.**		

<table>
<tr><th rowspan="2">Question</th><th rowspan="2">Objective</th><th rowspan="2">Objective Code</th><th rowspan="2">Score</th><th rowspan="2">Description</th><th colspan="2">Correct answer</th></tr>
<tr><th>Version A</th><th>Version B</th></tr>
<tr><td rowspan="6">8</td><td rowspan="3">Operations with integers</td><td rowspan="3">1</td><td>0</td><td>S made a mistake, or there is no evidence that S performed the operations that S attempted correctly.</td><td rowspan="3">6</td><td rowspan="3">3</td></tr>
<tr><td>0.5</td><td>S performed at least one operation correctly, but has at least one mistake.</td></tr>
<tr><td>1</td><td>There is evidence (work or a correct answer) that S correctly performed any operations that S attempted. Note: S may not have the correct answer here if S attempted incorrect operations but performed the operations correctly.</td></tr>
<tr><td rowspan="3">Order of operations</td><td rowspan="3">4</td><td>0</td><td>S did not correctly follow the order of operations.</td><td rowspan="3">6</td><td rowspan="3">3</td></tr>
<tr><td>0.5</td><td>S correctly followed the order of operations but has a mistake because S did not correctly square a negative integer. OR S did not complete the final step in the order of operations (divide).</td></tr>
<tr><td>1</td><td>S followed the order of operations, but may not have the correct answer if S made an arithmetic error.</td></tr>
</table>

<table>
<tr><th rowspan="2">Question</th><th rowspan="2">Objective</th><th rowspan="2">Objective Code</th><th rowspan="2">Score</th><th rowspan="2">Description</th><th colspan="2">Correct answer</th></tr>
<tr><th>Version A</th><th>Version B</th></tr>
<tr><td rowspan="6">9a</td><td rowspan="3">Operations with integers</td><td rowspan="3">1</td><td>0</td><td>S did not multiply correctly.</td><td rowspan="3">-24x^2 y</td><td rowspan="3">-30xy^2</td></tr>
<tr><td>0.5</td><td>S performed one of the integer multiplication steps correctly (neglecting variables) and either has a mistake on the second one or did not perform the second one.</td></tr>
<tr><td>1</td><td>S multiplied correctly and has the correct coefficient.</td></tr>
<tr><td rowspan="3">Using the rules of exponents</td><td rowspan="3">7</td><td>0</td><td>S has incorrect powers on both x and y.</td><td rowspan="3">-24x^2 y</td><td rowspan="3">-30xy^2</td></tr>
<tr><td>0.5</td><td>S has the correct power on x or y, but not both.</td></tr>
<tr><td>1</td><td>S has the correct power on both x & y.</td></tr>
<tr><td rowspan="5">9b</td><td rowspan="2">Operations with fractions</td><td rowspan="2">2</td><td>0</td><td>S reduced the numerical part of the fraction incorrectly or did not reduce.</td><td rowspan="2">(5x)/(9y^2)</td><td rowspan="2">(3x)/(8y^3)</td></tr>
<tr><td>1</td><td>S reduced the numerical part of the fraction correctly.</td></tr>
<tr><td rowspan="3">Using the rules of exponents</td><td rowspan="3">7</td><td>0</td><td>S has incorrect powers on both x and y.</td><td rowspan="3">(5x)/(9y^2)</td><td rowspan="3">(3x)/(8y^3)</td></tr>
<tr><td>0.5</td><td>S has the correct power on x or y, but not both. Note: S may not have done anything to the variables, and therefore has the correct exponent on x because nothing was done.</td></tr>
<tr><td>1</td><td>S has the correct power on both x & y.</td></tr>
<tr><td rowspan="2">11b (angle 2 only)</td><td rowspan="2">Operations with decimals</td><td rowspan="2">3</td><td>0</td><td>S did not correctly perform the operation that S attempted for angle 2.</td><td rowspan="2">147.6</td><td rowspan="2">148.3</td></tr>
<tr><td>1</td><td>There is evidence (work or a correct answer) that S performed the operation that S attempted for angle 2. S may not have the correct answer if S did not attempt the correct operation.</td></tr>
</table>

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	**Version B**
13a	Operations with decimals	3	0	S did not correctly perform any of the operations that S attempted OR S did not attempt any operations with decimals.	7,500	6,500
			1	There is evidence (work or a correct answer) that S correctly performed the operation that S attempted.		
13b	Operations with decimals	3	0	S did not correctly perform any of the operations that S attempted OR S did not attempt any operations with decimals.	1,000	2,000
			1	There is evidence (work or a correct answer) that S correctly performed the operation that S attempted.		
15	Operations with decimals	3	0	No evidence that S performed either operation correctly.	$1,182.50	$1,410.50
			0.5	S performed either the multiplication (tax) or addition (total) correctly, but not both.		
			1	S performed both the multiplication and addition that S attempted correctly.		
16c	Using the rules of exponents	7	0	S has an incorrect answer.	256 or 2^8	729 or 3^6
			1	S has a correct answer.		
16d	Using the rules of exponents	7	0	S has an incorrect answer.	1	1
			1	S has a correct answer.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
17a	Operations with integers	1	0	S did not correctly multiply when distributing OR S did not multiply at all when "distributing".	4x+6	3y+12
			1	S correctly multiplied the number in front of the parentheses times the constant term in the parentheses when distributing (not including negatives).		
	Combining like terms	5	0	S incorrectly combined the x terms or did not combine them at all.	4x+6	3y+12
			1	S correctly combined the two x terms that S had in the step prior to combining like terms.		
	Applying the distributive property	8	0	S did not distribute correctly to either term.	4x+6	3y+12
			0.5	S distributed correctly to only one of the terms OR S treated the problem as if the first two terms were also in parentheses and used FOIL to multiply (and did so correctly).		
			1	S distributed correctly to both terms, including negatives.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
17b	Operations with integers	1	0	S did not correctly combine the two integers that S had in the step prior to combining.	3y^2-y-5	4x^2-x-5
			1	S correctly combined the two integers that S had in the step prior to combining (or, S has the correct constant term if S did not show work).		
	Combining like terms	5	0	S combined terms incorrectly or combined terms that had different exponents.	3y^2-y-5	4x^2-x-5
			0.5	S combined either the y^2 terms or the y terms correctly, but not both.		
			1	S combined both the y^2 terms and the y terms correctly.		
	Applying the distributive property	8	0	S did not correctly distribute the negative sign.	3y^2-y-5	4x^2-x-5
			0.5	S correctly distributed the negative sign on one or two of the terms, but not all three.		
			1	S correctly distributed the negative sign on all three terms.		
18a	Operations with integers	1	0	S did not correctly multiply when distributing OR S did not multiply at all when "distributing".	7x-56	6x-54
			1	S correctly multiplied when distributing.		
	Applying the distributive property	8	0	S did not correctly distribute to either term in the parentheses.	7x-56	6x-54
			0.5	S distributed correctly to only one of the terms.		
			1	S distributed correctly to both terms, including negatives.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
19	Operations with integers	1	0	S performed none of the operations S attempted correctly.	8/3 or 2.6 repeating	14/3 or 4.6 repeating
			0.5	S performed at least one operation correctly, but has at least one mistake.		
			1	S performed all operations attempted correctly (even if S only attempted a small number of operations). **Note: It's acceptable for S to give 2.6 as the answer.**		
	Combining like terms	5	0	S did not combine the x terms correctly.	8/3 or 2.6 repeating	14/3 or 4.6 repeating
			1	S combined the x terms correctly.		
	Solving linear equations	6	0	S did not isolate the x term correctly or divide by the coefficient of x as part of S's strategy.	8/3 or 2.6 repeating	14/3 or 4.6 repeating
			0.5	S correctly isolated the x term but did not finish the problem correctly OR S made a mistake when isolating the x term but correctly divided by the coefficient of x in the last step.		
			1	S correctly isolated the x term and divided by the coefficient of x (may not have the correct answer if S made a mistake distributing or combining like terms).		
	Applying the distributive property	8	0	S did not correctly distribute to either term on the left side of the equation.	8/3 or 2.6 repeating	14/3 or 4.6 repeating
			0.5	S correctly distributed to only one term on the left side.		
			1	S correctly distributed to both terms on the left side of the equation.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
20	Operations with decimals	3	0	S performed neither of the two operations correctly.	-16.5	-13.5
			0.5	S performed at least one (but not all) operations that S attempted correctly.		
			1	S correctly performed every operations S attempted (may not have correct answer if S did not correctly solve for x).		
	Combining like terms	5	0	S did not have the correct strategy for combining the x terms.	-16.5	-13.5
			1	S had the correct strategy to combine the two x terms, but may have made an arithmetic error.		
	Solving linear equations	6	0	S did not have either part of the strategy correct.	-16.5	-13.5
			0.5	S had one, but not both steps of the strategy below correct.		
			1	S had the correct strategy: isolate the x term, divide by the coefficient of x.		
21	Operations with fractions	2	0	S did not correctly perform any of the operations S attempted.	1/8	1/8
			0.5	S correctly performed at least one, but not all, of the operations attempted.		
			1	S correctly performed all of the operations S attempted.		
	Solving linear equations	6	0	S did not have either part of the strategy correct.	1/8	1/8
			0.5	S had one, but not both steps of the strategy below correct.		
			1	S had the correct strategy: isolate the x term, divide by the coefficient of x.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
22	Operations with decimals	3	0	S did not correctly multiply 3.14 by something.	153.9 ft^2	254.3 ft^2
			1	S correctly multiplied 3.14 by whatever number S had (may not have the correct answer if S either did not square r correctly, did not square r at all, or used d). **Note: Unit does not matter; rounding does not matter.**		
24b	Operations with integers	1	0	S did not correctly perform any of the operations S attempted.	17	12
			0.5	S correctly performed at least one, but not all, of the operations S attempted.		
			1	S correctly performed all of the operations S attempted.		
	Solving linear equations	6	0	S did not have either part of the strategy correct.	17	12
			0.5	S had one, but not both steps of the strategy below correct.		
			1	S had the correct strategy for solving S's equation: isolate the x term and divide by the coefficient of x.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					Version A	Version B
25c	Operations with integers	1	0	S did not correctly perform any of the operations S attempted.	x=3 (does not matter if S has the other sides correct)	x=6 (does not matter if S has the other sides correct)
			0.5	S correctly performed at least one, but not all, of the operations S attempted.		
			1	S correctly performed every operation S attempted.		
	Combining like terms	5	0	S did not combine like terms correctly.	x=3	x=6
			1	S combined like terms correctly.		
	Solving linear equations	6	0	S did not isolate the x term correctly or divide by the coefficient of x as part of S's strategy.	x=3 (does not matter if S has the other sides correct) **Note: S may have chosen another variable for side 2.**	x=6 (does not matter if S has the other sides correct) **Note: S may have chosen another variable for side 2.**
			0.5	S correctly isolated the x term but did not finish the problem correctly OR S made a mistake when isolating the x term but correctly divided by the coefficient of x in the last step.		
			1	S correctly isolated the x term and divided by the coefficient of x (may not have the correct answer if S made a mistake distributing or combining like terms). **Note: S may not have the correct answer here if S's equation was incorrect.**		

COLLEGE ALGEBRA RUBRIC

<table>
<tr><th rowspan="2">Question</th><th rowspan="2">Objective</th><th rowspan="2">Objective Code</th><th rowspan="2">Score</th><th rowspan="2">Description</th><th colspan="2">Correct answer</th></tr>
<tr><th>SL</th><th>L</th></tr>
<tr><td rowspan="6">#1c/ Pt1#2</td><td rowspan="6">Write the equation of a line in slope-intercept form given a point and the slope</td><td rowspan="6">1</td><td>0</td><td>S left the problem blank or made no progress as outlined below. Give this score in the lecture section if S rearranged the given equation to be in slope-intercept form.</td><td rowspan="6">f(x)= -3/2x+5</td><td rowspan="6">y= -3/2x - 5</td></tr>
<tr><td>0.2</td><td>S used two points (one of which was the y-intercept) rather than the slope, plugged the points into y=mx+b, and attempted to solve for the slope but has a mistake.</td></tr>
<tr><td>0.2</td><td>S attempted to use the slope and a point to find the equation, but the point given (or selected by S) is not on S's line and S gave an equation not in slope-intercept form.</td></tr>
<tr><td>0.4</td><td>S used two points (one of which was the y-intercept) rather than the slope, plugged the points into y=mx+b, and solved correctly for the slope but S did not put the final answer in slope-intercept form. Thus, both of the points they chose are on the line.</td></tr>
<tr><td>0.5</td><td>S attempted to use the slope and a point to find the y-intercept, but the point given is not on S's line and S has the correct form: y=mx+b or f(x)=mx+b.</td></tr>
<tr><td>0.6</td><td>S used the slope and point correctly but left out the "x" or "y", and S used some other form (point-slope or standard): y-a=mb, a+b=c, ax+b=c, a+by=c, etc.</td></tr>
</table>

<table>
<tr><th rowspan="2">Question</th><th rowspan="2">Objective</th><th rowspan="2">Objective Code</th><th rowspan="2">Score</th><th rowspan="2">Description</th><th colspan="2">Correct answer</th></tr>
<tr><th>SL</th><th>L</th></tr>
<tr><td rowspan="4">#1c/ Pt1#2</td><td rowspan="4">Write the equation of a line in slope-intercept form given a point and the slope</td><td rowspan="4">1</td><td>0.6</td><td>S used two points (one of which was the y-intercept) rather than the slope, plugged the points into y=mx+b, and solved correctly for the slope. Thus, both of the points they chose are on the line and the final equation is in slope-intercept form.</td><td rowspan="4">f(x)= -3/2x+5</td><td rowspan="4">y= -3/2x - 5</td></tr>
<tr><td>0.8</td><td>S used the slope correctly and has the correct y-intercept but left out the "x", and S used slope-intercept form: y=m+b or f(x)=m+b</td></tr>
<tr><td>0.9</td><td>S correctly used the slope and a point to write a linear equation. Note: It does not matter if the S has the correct slope, just that they have the correct equation given whatever slope and point they chose to use. S did not give the equation in slope-intercept form, but S did give a correct equation in some other form (point-slope or standard).</td></tr>
<tr><td>1</td><td>S correctly used the slope and a point to write a linear equation in point-slope form. Note: It does not matter if the S has the correct slope, just that they have the correct equation given whatever slope and point they chose to use.</td></tr>
</table>

Question	Objective	Objective Code	Score	Description	Correct answer	
					SL	L
#4/ Pt2 #8a&b	Write the equation of an exponential function given two data points.	2	0	S has no progress or left the question blank.	f(x)=4*3^x	f(x)=4000*(3/2)^x
			0.1	S attempted to find a linear equation that fits the points, but did not finish or did so incorrectly.		
			0.2	S found a linear equation that fits the points.		
			0.5	S has the correct form (f(x)=C*a^x), but both the coefficient (C) and common ratio (a) are incorrect.		
			0.7	S has the correct form (f(x)=C*a^x), but has either the coefficient (C) or common ratio (a) incorrect.		
			0.8	S correctly found C and a but did not plug the results into the final equation OR S plugged the values in incorrectly. S may have something like the generic form as the final answer, or S may only have work and no final answer. **Note: In the lecture section, give this score if S correctly found C and a but plugged them in incorrectly in part (b).**		
			0.8	S left out the "x" in the final answer but has the correct coefficient (C) and common ratio (a). Answer has the form: f(x)=C*a, f(x)=C*a^1, etc. **Note: See notes for a score of 1 for how to score lecture courses.**		

Question	Objective	Objective Code	Score	Description	Correct answer	
					SL	L
#4/ Pt2 #8a&b	Write the equation of an exponential function given two data points.	2	0.9	S has the correct process for finding the equation (plug the two points into f(x)=C*a^x and solve for C and a), but has a small arithmetic error or "typo" which results in an incorrect answer.		
			1	S has the correct answer. **Note: For lecture classes, look at part (b) to determine if S plugged C & a in correctly. Give full credit if they plugged C & a in the correct spots but already plugged in the value to work part (b) - that is, they don't have an "x" in the equation but plugged 2.5 into the correct spot.**		
#6/ Pt2#5	Model a situation with a system of two linear equations and solve	3	0	S made no progress or left the problem blank.	a=64, c=36	a=1200, c=800
			0.5	S set up the correct equations (or has a correct augmented matrix) but made no attempt to solve them (or reduce the matrix to RREF).		
			0.7	S has incorrect initial equations, but solved the equations correctly.		
			0.9	S set up the correct equations but made one or more errors which resulted in an incorrect solution.		
			1	S correctly solved for both variables.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					SL	L
#7/ Pt2#7	Use properties of logarithms to write an expression as a single logarithm	4	0	S made no progress (did not apply any of the properties correctly) or left the problem blank.	log_3(1/x)	log (xz^2/y^3)
			0.3	S correctly applied at least one of the log properties, but has two or more mistakes applying the properties (do not count arithmetic errors here) or did not finish the problem		
			0.5	S correctly applied at least one of the log properties, but has one mistake applying the properties (do not count arithmetic errors here). In lecture section, if S has two of the variables switched (such as log (y^3 z^2/x), count this as only one mistake.		
			0.9	S correctly applied both of the log properties to get a single log expression but did not simplify completely (or made a mistake simplifying) and/or has an arithmetic mistake that causes the answer to be incorrect.		
			1	S has the correct answer.		

Question	Objective	Objective Code	Score	Description	Correct answer	
					SL	L
#8/ Pt2#6	Solve an exponential equation	5	0	S made no progress or left the problem blank.	x = (-3log3)/(log3-log7) OR log27/log(7/3) OR 3.889	x=ln2/2 or 0.347
			0.2	S has a small amount of progress toward solving the equation, but none of the steps outlined below.		
			0.5	S attempted to use log somehow to solve the equation, but did not have a complete strategy.		
			0.6	S has the correct overall strategy, but made a mistake somewhere while solving (such as adding something to both sides when it should be subtracted, or forgetting to do an operation on both sides of the equation).		
			0.7	S has the correct strategy but made two or more arithmetic mistakes.		
			0.9	S has the correct strategy but made a small arithmetic mistake somewhere and doesn't quite have the correct answer.		
			1	S has the correct answer. Give full credit if S rounded.		

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